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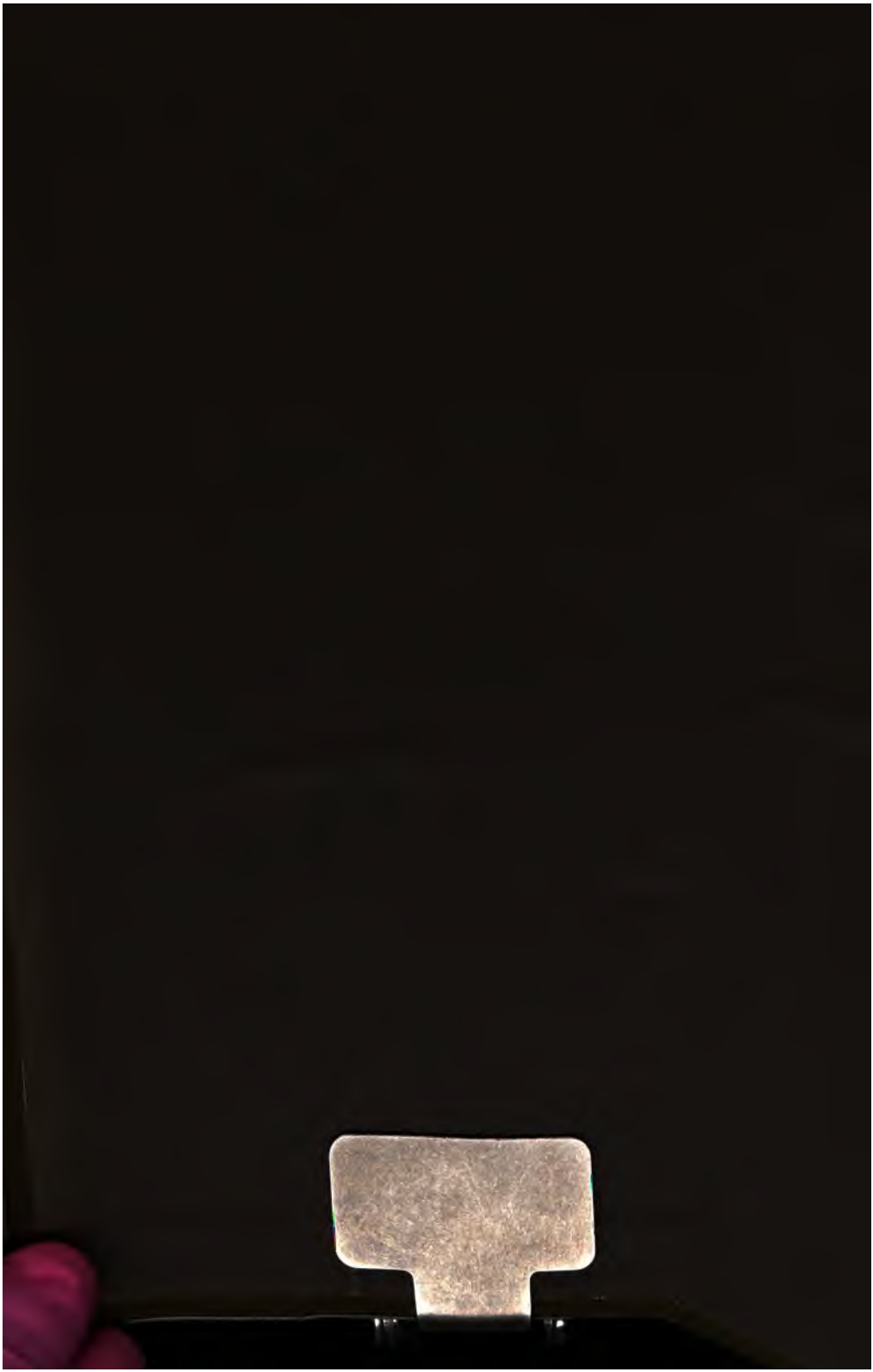

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NATURE'S HYGIENE.

NATURE'S HYGIENE:

A Systematic Manual of Natural Hygiene.

CONTAINING ALSO AN ACCOUNT OF

THE CHEMISTRY AND HYGIENE OF THE EUCALYPTUS AND THE PINE.

BY

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PREFACE.

DURING the four years that have elapsed since the first edition of this work was issued, so much attention has been paid to sanitary matters, that I have found it necessary to re-write the greater part of it, and to add several new chapters dealing with Water Supply, Sewage, Infectious Diseases, and the Treatment of the Sick. At the same time I have given even more attention than in the first edition, to the process of oxidation as carried on in nature; and I think the book will be found to contain an accurate account of present knowledge concerning the relations of micro-organisms to disease. All matter relating to the chemistry and hygiene of the eucalyptus and the pine has been retained; but it has been found desirable to divide the work into two parts, one dealing in particular with this subject (which has been my special study), and the other with the general principles of natural hygiene.

I take this opportunity of expressing my opinion

that great public benefit would result from the appointment of chemical officers to act in conjunction with medical officers of health. It is notorious that medical men and engineers are not qualified by their special education and training, to deal with many questions which are of the greatest importance to public health and wealth; and I entertain a strong conviction that by the appointment of efficient chemists as officers to act under Sanitary Authorities and Local Boards, a saving would be effected to rate-payers generally. Chemical officers, if appointed in accordance with my suggestion, should do the work at present conducted by public analysts, and to them should be referred all matters in connection with water supply, gas supply, and the disposal and utilisation of sewage and refuse. In order to obtain the services of efficient chemists, it would, of course, be essential to offer adequate remuneration for the duties that would be imposed upon them. I beg to commend this suggestion to the earnest attention of my readers, and to Members of Parliament in particular.

In conclusion, I hope this new edition of my book will prove useful to many.

CHARLES T. KINGZETT.
Analyst and Consulting Chemist.

"TREVENA," AMHURST PARK,
LONDON, N., *December*, 1884.

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NATURE'S HYGIENE.

CHAPTER I.

INTRODUCTORY.

Constitution of Matter—Chemical Elements—Chemical Compounds—Law of Combining Proportions—Synthesis and Decomposition—Symbols—Formulæ—Reactions and Equations.

SINCE, in the following pages, there will be frequent references to chemical principles and chemical changes, it is desirable that readers should be prepared in this first chapter to understand such matters as they arise.

By the science of chemistry it has been ascertained that our globe, comprising all substances that are found in it and upon it, whether entering into the composition of minerals, vegetables, or animals, is built up of a number of ultimate principles (called elements), and compounds resulting from their chemical combination. By the word "element" it is intended to represent a substance which cannot undergo change, and which cannot therefore be resolved into two or more distinct substances.

Whether elements are really final or distinct substances is not absolutely known. It may be that means will yet be found by which chemists will be enabled to decompose them into more ultimate principles, and it may also be that they are really identical in substance,—that they are, in fact, composed of primordial matter, and only differ in properties according to the various conditions under which they are revealed to us as so-called elements. But, however that may be, the fact remains that up to the present time such means have not been found.

The elemental state, as at present understood by chemists, may be illustrated by figures. Just as numbers are composed of units, so are chemical compounds composed of elements; and in the same sense that a numerical unit is something that cannot be divided, so also are the chemical units or elements indivisible. From metallic lead, nothing but metallic lead can be extracted; from gold, nothing but gold can be obtained, and so on.

There are three states of matter, not different in essence, but dependent upon pressure and temperature. To illustrate this fact we may refer to the elemental metal called mercury (quicksilver), which, at the ordinary temperature of the atmosphere, is a fluid: if heated, it assumes the state of vapour, and it may be distilled just as water is distilled in order to purify it: on the other hand, it can be frozen into a hard solid.

A chemical compound results from the com-

bination of two or more chemical elements, but it must not be supposed to be a mere mixture of them. A quantity of sulphur may be admixed with lead shots, but the admixture is not a chemical combination; in proof of this, there is the fact that the shots may be mechanically removed one by one from the sulphur, thus dividing the lead wholly from the sulphur. A separation of this sort is in no sense related to what is known in chemistry as decomposition. If, on the other hand, the mixed lead and sulphur be placed in a crucible and strongly heated by fire, real chemical combination occurs; the lead disappears and the sulphur disappears, and the product is a substance which is called sulphide of lead, the properties of which are not those of a mere mixture of the lead with the sulphur, but are peculiar to the combination.

Again, if metallic mercury be gently heated in a suitable vessel and exposed to the air, it absorbs oxygen therefrom and becomes coated with a yellow substance, which we know to be an oxide of mercury; but by no mere admixture can oxygen and mercury be made to assume this form. The use of heat, light, electricity, or some other agency, is generally requisite to bring about chemical change.

Further, if the yellow oxide of mercury, produced as above described, be exposed to a greater heat than that which is employed in its production, it is decomposed, yielding oxygen gas and metallic mercury as its products.

The total number of elements at present known to

chemists is about sixty-five, and the following is a list of the more important ones :—

Name.	Symbol.	Combining Weight.	Name.	Symbol.	Combining Weight.
Aluminium	Al	27·5	Lead	Pb	207
Antimony	Sb	122	Magnesium	Mg	24
Arsenic	As	75	Manganese	Mn	55
Barium	Ba	137	Mercury	Hg	200
Bismuth	Bi	210	Nitrogen	N	14
Boron	B	11	Nickel	Ni	59
Bromine	Br	80	Oxygen	O	16
Calcium	Ca	40	Phosphorus	P	31
Carbon	C	12	Platinum	Pt	197·1
Chlorine	Cl	35·5	Potassium	K	39·1
Chromium	Cr	52·5	Silicon	Si	28
Copper	Cu	63·4	Silver	Ag	108
Cobalt	Co	59	Sodium	Na	23
Fluorine	F	19	Strontium	Sr	87·6
Gold	Au	196·6	Sulphur	S	32
Hydrogen	H	1	Tin	Sn	118
Iodine	I	127	Zinc	Zn	65
Iron	Fe	56			

The few compounds which have been hitherto named are very simple in character. In illustration of a more complex one, we may name limestone. This substance is composed of calcium, carbon, and oxygen. When heated, as in a kiln, a gas is given off which is known as carbonic anhydride (carbonic acid), and lime is left behind. Here, we have the case of a compound which, by the agency of heat, is resolved into two other compounds; for carbonic anhydride is composed of carbon and oxygen, and lime is composed of calcium and oxygen.

Heat is by no means the only agency which may be employed to effect the decomposition or synthesis

of compounds. For instance, an electric current may be employed to decompose water into its constituent elements (oxygen and hydrogen gases), and an ordinary photograph is but the result of a chemical change effected in a silver compound by the agency of light.

Many of the compounds which are present in the bodies of living beings are of a very complicated nature. For instance, albumin (white of egg) is composed of five elements—carbon, hydrogen, nitrogen, oxygen, and sulphur; and by its gradual disintegration, a great number of intermediate substances may be obtained before arriving at the most simple products. Nor is albumin the most highly complex substance, for there are several substances present in brain matter, for example, which have, probably, larger molecular proportions.

The synthesis and decomposition of substances is not alone effected by physical causes; they are effected also as acts of vitality. Complex substances present in the body of man are resolved into simple substances, while comparatively simple substances taken as food are also elaborated in the animal body into complex substances. What is true of man is true also of other living organisms, and man in his turn may become the prey of minute organisms effecting decomposition in his living body.

The ordinary process of putrefaction is one of decomposition effected by micro-organisms.

Nor is it always necessary to make use of outside agencies to effect chemical change. Chemical affinity,

as it is termed, is often sufficient of itself to effect combination or decomposition. The chemical affinity of phosphorus for oxygen is so strong, that ordinarily it is requisite to preserve phosphorus under water. When exposed to air or oxygen, it greedily combines with the oxygen, and heat is generated so rapidly in consequence, that the phosphorus bursts into flame. Oxides of phosphorus result from this combination. The process itself is known as one of oxidation, but there are degrees of oxidation. For instance, if the phosphorus be partially submerged in water when exposed to the air, the temperature is thus kept down, and the oxidation proceeds much more slowly; and, what is more important to note, the products of the chemical changes that proceed are more numerous and are not identical with those obtained in the dry oxidation; for, in addition to an oxide of phosphorus, there are produced ozone and peroxide of hydrogen, two very interesting substances about which we shall have more to say later on.

The chemical elements differ in weight or specific gravity. Hydrogen is the lightest known substance, air being 14·43 times as heavy, and platinum is the heaviest known substance. Of course we are here speaking of relative or specific weight, not absolute weight.

The density of a chemical element in the state of gas represents the relative weight of a given volume thereof at a standard pressure and temperature, the same volume of hydrogen being taken as unity, and

the densities of all the chemical elements which assume, or may be made to assume, the gaseous state, are identical with their combining weights.

Chemical combination always takes place between definite proportions of the different substances. For instance, when sulphur is burnt in the open air (as in fumigating a room), every 32 parts of sulphur always combine with twice 16 parts of oxygen. We say twice 16 parts of oxygen rather than 32, since it is possible for 16 parts of oxygen to enter into other combinations, but never less than 16 parts are involved in any chemical change.

The combining proportions of the elements are not in all cases, however, identical with their specific gravities, and must not be confused therewith. Hydrogen is taken as the unit, since it enters into combination with the lowest equivalent weight. The atoms of hydrogen are not supposed to be any smaller than the atoms of other elements, but only lighter; and the combining proportions of the elements represent, generally speaking, their atomic weights. At least, it is found, practically, that they combine in these constant proportions, or in multiples of them. It is in this precise quantitative way that chemical combination occurs. Common salt, for example, contains in every 58·5 parts, 23 parts by weight of metallic sodium, and 35·5 parts of the gas chlorine. The molecular weight of common salt (chloride of sodium) is therefore 58·5, and it means that in order to produce a molecule of the compound, one atom of each of its two constituent elements must be com-

bined; the atom of each being the smallest relative weight of each (compared to hydrogen taken as the standard) that ever enters into chemical combination. This explains the figures (atomic weights) that are placed against the names of the chemical elements in the preceding table.

We are now in a position to understand the use made in chemistry of symbols and formulæ. For the sake of brevity, chemists indicate the metal aluminium by the symbol Al; bromine by Br; sodium by Na (derived from the word natrium); potassium by K (derived from kalium), and so forth. But Na does not merely indicate sodium, but it stands for what is called one atom of the element; that is, 23 parts by weight, that being its combining proportion. Similarly, chlorine is represented by the symbol Cl, which means 35·5 parts by weight, or its combining proportion, that being the quantity which invariably combines with 1 part of hydrogen represented by the symbol H. Thus HCl stands for hydrochloric acid; its molecular weight is 36·5, and every 36·5 parts by weight are found upon analysis to yield 35·5 parts by weight of chlorine, and 1 part by weight of hydrogen. From such analytical facts the percentage composition of any substance may, of course, be readily calculated.

The formula, then, for hydrochloric acid is HCl; that for sulphuric acid is H_2SO_4; that for nitric acid HNO_3.

Baryta, or oxide of barium, is represented by BaO; peroxide of barium is formulated BaO_2. Now when

peroxide of barium is placed in contact with hydrochloric acid, a chemical change or reaction takes place, and it is indicated by the equation—

$$BaO_2 + 2HCl = BaCl_2 + H_2O_2.$$

This equation is intended to represent the fact that 1 molecule of peroxide of barium, when placed in contact with 2 molecules of hydrochloric acid, results in the production of 1 molecule of chloride of barium, and 1 molecule of peroxide of hydrogen. It is evident that the sum of the products is equal to the sum of the substances originally employed. Thus we have employed—

1 atom or 127 parts of barium 2 atoms or 32 parts of oxygen	Present in 1 molecule of peroxide of barium.
2 atoms or 2 parts of hydrogen 2 atoms or 71 parts of chlorine	Present in 2 atoms or 1 molecule of hydrochloric acid.

And we obtain as the result of the chemical action—

1 atom or 127 parts of barium 2 atoms or 71 parts of chlorine	Present in 1 molecule of chloride of barium.
2 atoms or 2 parts of hydrogen 2 atoms or 32 parts of oxygen	Present in 1 molecule of peroxide of hydrogen.

It will be seen that altogether there are employed 232 parts by weight, and that there are obtained 232 parts by weight.

This equation affords an incidental proof that matter is indestructible; its form may be changed, but the substance cannot disappear or be destroyed. If, therefore, in the study of any chemical change the sum of the products found upon analysis is not equal to the parts by weight of the substances originally

used, it is known to the operator that the analysis is imperfect, and that some product has been missed.

There is one further consideration worth mentioning in connection with this subject of chemical combination. The formula H_2O not merely implies that 2 parts by weight of hydrogen are combined with 16 parts by weight of oxygen in each molecule of water: it also expresses a relation by volumes of the chemical elements in combination. If a molecule of water be subjected to analysis, it yields 2 volumes of hydrogen and 1 volume of oxygen.

Again, the formula HCl (hydrochloric acid) implies a combination of equal volumes of hydrogen and chlorine; and the formula NH_3 (ammonia) implies a combination of 3 volumes of hydrogen with 1 of nitrogen.

Hygiene is largely concerned with the chemical composition and properties of the air, water, and animal and vegetable substances, and what has gone before will enable the reader to duly understand what has to be said in relation to these subjects in later portions of this volume.

CHAPTER II.

OXYGEN, OZONE, NITROGEN, CARBONIC DI-OXIDE, HYDROGEN, WATER, AND PEROXIDE OF HYDROGEN.

Oxygen.

Symbol O. Atomic Weight 16.

IN the early days of the Royal Society, when its meetings were held at Oxford, the Hon. Robert Boyle directed the attention of its members to a number of interesting experiments which he, together with his assistant Dr. Hooke, had made upon ordinary air. Among these observations he showed that animals which were confined in a limited volume of air died after a short time. John Mayow, who attended these meetings, became greatly interested in this subject, and continued the research thus originated. He ascertained (1674) that in breathing, animals do not consume the whole of the air which is inspired, and that, indeed, the air consists of two gases, one of which is of no direct use in sustaining life. This gas we now know as "nitrogen."

It will be seen that Mayow had, as a matter of fact, discovered "oxygen" gas, although in a negative sort of way; but, owing to the erroneous views

then prevalent, his discovery was allowed to be forgotten, or nearly so, for a hundred years. Then Priestley, who occupied himself with continued observations upon gases, succeeded—it may almost be said accidentally—not only in rediscovering oxygen, but also at the same time in making it from a solid substance. It will be remembered by all students of chemical history that, in 1774, Priestley obtained this gas by exposing the red oxide of mercury to a high temperature; and it further appears that Scheele (a Swedish apothecary of famous memory) made the same discovery both simultaneously and independently. Priestley not merely collected oxygen gas, but he ascertained also its powers to support combustion and maintain life. At that time he wrote, "Who can tell whether this pure air may not at last become a fashionable luxury? As yet, only two mice and myself have had the privilege of breathing it."* In spite of all this, he very imperfectly understood his own results.

The Parisian Lavoisier (born 1743) was a man of his day. After revolutionizing chemical science, he himself was sacrificed to a political revolution. He introduced the balance into chemistry, and whereas Priestley had obtained oxygen and mercury from the red oxide, Lavoisier reconstructed the compound from its elements, and showed that upon heating a given quantity of the oxide, it evolves just the same amount of oxygen gas as is consumed in

* "Short History of Natural Science," Buckley, p. 284.

its preparation. In short, he thus demonstrated the fact that mercury and oxygen combine in definite proportions.

Oxygen may be prepared in the laboratory by a number of methods, the simplest of which consists in exposing certain metallic oxides * to high temperatures, when decomposition occurs; oxygen is thus liberated in the gaseous state, while the metals or their lower oxides are left behind.

Oxygen is best known, however, as a constituent of the air we breathe, serving in the process of respiration to oxidise or burn up the carbonaceous and other matters present in the blood of animals, and with which it comes into contact through the medium of the lungs. The details of this process and its results will be studied in the next chapter.

At the ordinary temperature and atmospheric pressure, oxygen is a colourless, tasteless gas; but it has been quite recently demonstrated by M. Raoul Pictet and M. Cailletet, that when reduced to a temperature of 140°C. under a pressure of 320 atmospheres, oxygen assumes the liquid form.

As Liebig is reported to have said that the best reagent for ammonia is the nose, so it may be said, oxygen is characterised by its power of oxidation. In cases where this process is carried on rapidly, so that it is attended with the evolution of light and heat, combustion is said to occur. For instance, if a piece of charcoal be ignited and then

* Combinations of metals with oxygen.

thrown into a globe filled with oxygen, the oxidation, which in the atmosphere merely kept the charcoal at a dull red heat, is now so intensified that the combustion is continued with great avidity.

In an ordinary grate fire we have the best illustration of the process of oxidation; the coal and wood, being of a carbonaceous nature, only require the application of heat to enable the oxygen in the atmosphere to enter into chemical combination with their constituent particles, and when once this process of combination has commenced, the heat with which it is attended, is sufficient to keep the combustion (oxidation) going. In this way the carbon of the fuel combines with the atmospheric oxygen to form carbonic dioxide.

Beyond its power to maintain life and support combustion, oxygen gas exhibits but few direct chemical reactions which are not also shared by ozone and peroxide of hydrogen. It differs from these two last-named substances, however, in being less active in its properties. Thus, when brought into contact with a solution of iodide of potassium, it exercises no influence upon it. It has no colour, taste, or smell; it is only slightly soluble in water, 100 volumes of this fluid dissolving 4·11 volumes of the gas at 0°C., and 2·99 volumes at 15°C. (ordinary temperature).

It has no action on litmus paper and does not oxidise silver, while it is stable at all temperatures. In oxygen, therefore, we have a substance of such marked general negative characters, that we can

readily and unmistakably discriminate between it on the one hand and ozone and peroxide of hydrogen on the other hand.

Ozone.

Molecular Symbol O_3. *Molecular Weight* 48.

It was about ten years after the discovery of oxygen when Van Marum, of Holland, observed that upon this gas being subjected to the passage of electric sparks, it acquired a peculiar fishy odour; and it is said that shortly afterwards, Cavallo discovered its disinfecting value, and applied it as a remedy to fœtid ulcers.*

In 1826, Dr. John Davy recognised the presence of a similar principle in the atmosphere, thus explaining the odour often referred to in history as having been observed during storms and periods of electrical disturbance. It was not, however, till 1839 that any precise knowledge was obtained regarding the substance in question. M. Schönbein, of Basle, who was then engaged in an investigation of the electrolytic decomposition of water, noticed the same odour in the apartment in which he conducted his experiments, and this led him to a prolonged research, having for its object the elucidation of the nature and properties of this gaseous principle, which from its odour he named "ozone."

He ascertained that a certain amount of this

* "Ozone and Antozone." by Dr. Cornelius B. Fox, p. 4.

substance is mixed with the oxygen which is evolved at the positive pole during the voltaic decomposition of water, and further observed a number of its oxidising effects.

The nature of ozone proved a very hard nut for chemists to crack, and the task has only been accomplished by men now living.

Schönbein at one time considered ozone to be a compound of oxygen with hydrogen. Peroxide of hydrogen being oxygenated water,* or a substance containing in its molecule more oxygen than water does, and its oxidising characters being considered as due to the ease with which it parts with the extra oxygen, Schönbein was led to regard ozone as peroxygenated water, or in other words, a more highly oxygenated compound than peroxide of hydrogen. Thus, to use the notation now employed by chemists, Schönbein represented ozone as H_2O_3, peroxide of hydrogen being H_2O_2, and water being H_2O.

Williamson supported Schönbein in this opinion, which was afterwards proved to be erroneous by a long series of investigations conducted by numerous chemists, among whom may be named Becquerel, Frémy, Marignac, De la Rive, Andrews, Soret, and Brodie. It was, first, shown that pure ozone is free from hydrogen, and therefore yields no

* This must not be understood as aërated water, or water containing dissolved oxygen, but water chemically combined with more oxygen and not simply admixed.

water during combustion; next, it was demonstrated that the matter of ozone is identical with the matter of oxygen; and, finally, by the classical researches of Andrews and Brodie (the latter of whom particularly investigated the volumetric relations of ozone), that ozone is oxygen in a condensed state. Not condensed in the sense that a given volume of gas may be made to occupy a smaller space by the influence of compression, but in the sense that the constituent atoms are so arranged that each whole molecule of ozone contains three atoms in the space occupied by a molecule of oxygen consisting of two atoms. While this demonstration was due to Andrews and Brodie, the view which it proved to be correct is to be credited to Odling, who with a characteristic keenness of perception, discerned the truth before it was established.

The superior oxidising powers of ozone, as compared with those of ordinary oxygen, are supposed to be due to the state of its density, to which reference has just been made.

The best proof that can be given of the identity of the matter of oxygen with that of ozone consists in the ease with which it is possible to convert oxygen into ozone, and to effect also the converse reaction. Suppose that we take 100 volumes of oxygen gas, and subject it to the electric discharge until it measures 92 volumes, we shall by this time have produced a definite amount of ozone. This can be shown by removing some of the gas and submitting it to different tests. But if, instead of

taking away any of the condensed gas, we raise it to a temperature of, say, 240°C., we shall find that for the 100 volumes of oxygen originally employed we now once more obtain 100 volumes at the same temperature and pressure. In other words, ozone is resolved at an elevated temperature into ordinary oxygen.

This identity of oxygen and ozone is not the least more remarkable than the identity presented by carbon in its ordinary forms. We have carbon in the forms of the diamond, graphite, and lamp-black; and the properties of these substances are as diverse as those of ozone and oxygen.

One fact must be stated in particular here, because when we get further on, we shall find it of considerable importance. It is this: whereas when ozone is exposed to contact with many chemical substances it suffers decomposition, yielding up its third atom of oxygen to the oxidisable matter and liberating ordinary oxygen, yet when submitted to contact with ordinary turpentine the whole molecule of the ozone is absorbed; no oxygen remains behind. For a knowledge of this fact we are indebted to Soret.

The presence of ozone in the atmosphere was first assumed when Dr. John Davy obtained certain reactions with ordinary air, which were then considered to be characteristic of ozone; and as Cavallo and others had found ozone to possess marked disinfecting powers, more importance was attached to atmospheric ozone than the subject, perhaps, deserved.

The observations of Dr. Davy were repeated and

extended by others, and as the oxidising powers of ozone became better known, there arose in the minds of men the idea that this substance constitutes nature's purifier. This idea received the more credence since Schönbein had taught that every process of slow oxidation occurring in nature is accompanied by the formation of ozone, and because Kossman and Daubeny had stated that, under certain conditions, the same substance was produced by the green parts of plants.

The amount of work which has been devoted to the study of ozone as occurring in the atmosphere, and its relation to storms and winds, is almost beyond belief, and the task of collecting or summarising such investigations would be, perhaps, one of supererogation. It will certainly not be attempted here, and more particularly since Dr. Fox has very carefully performed the task already.* To his work we refer the reader who may feel disposed to proceed upon the study, while for the purposes of this treatise it will suffice to bring some few facts prominently to the reader's attention. In the first place, then, the majority of persons undoubtedly attach great importance to atmospheric ozone, and believe it to be the greatest purifying influence in nature; many going so far as to assert that zymotic disease exhibits a definite relation to ozone in the sense that when ozone is absent from the atmosphere, disease occurs and spreads, and that where present, zymotic disease

* "Ozone," etc. By Dr. Cornelius Fox. Churchill.

is almost unknown. It seems a vast pity to upset notions which have taken so deep a root in men's minds, but the truth must be told by scientific men, and the truth is, that nearly all the observations which have been made on the subject are inconclusive.

It was pleasant enough to resort annually to the seaside in the firm belief that there ozone occurred plentifully, and miasmatic poisons could not endure; but, as a matter of fact, there is little evidence to show that, so far at least as ozone is concerned, the seaside is any healthier than the flats and marshes of Lincolnshire or the hills of Devonshire.

And now one word in explanation. The chemical reagents and tests which have been applied by different observers in determining the presence and amount of ozone in the atmosphere under various circumstances are not alone influenced by ozone; they are also influenced by peroxide of hydrogen, and there is, at present, no reliable and practicable method for testing and estimating the one substance without including the other.

There is generally some amount of truth in any doctrine or belief which may be held by a large number of persons, and as readers of the foregoing sentences may have suffered some discomfort in feeling that their pet theory was here demolished, it is pleasant to restore their comfort, and place it upon a more enduring basis. My readers, then, may rest content with the assurance that even if ozone does not occur in the air so freely as previously believed,

yet another substance does, and one, too, of greater sanitary value, viz., peroxide of hydrogen.

Although it cannot be said with certainty that ozone ever occurs in the atmosphere at all, its presence in minute amount is very probable, and more particularly because there are times and conditions when ozone must, presumably, be produced in the atmosphere. It must yet be distinctly understood that there is no known test for ozone admitting of application which is not also affected by peroxide of hydrogen.

When Dr. Daubeny in 1866* stated that his researches tended to show that atmospheric ozone is generated almost exclusively by the green parts of plants, he was guided by the fact that the oxygen which is emitted by plants in the daytime, when brought into contact with iodide of potassium, liberated iodine therefrom; this result, however, is producible by peroxide of hydrogen, and also by ordinary oxygen in the presence of sunlight.

Dr. Daubeny was supported in his views by M. Kossman and others; but M. Cloez, from some carefully conducted experiments, arrived at the conclusion that the liberation of iodine and consequent colouration of the ozone test-papers in Daubeny's experiments was due to the combined action of humid oxygen and solar light upon the iodide of potassium, and this conclusion is confirmed by more recent observations of the late Dr. Angus Smith.

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* See *British Association Report*, also *Journ. Chem. Soc.*, 1867, 19.

Bellucci* passed currents of air (free from ozone) through bell-jars containing living plants or recently cut branches and leaves, and he also found that if the tubes containing the air were protected from daylight, when it came in contact with the potassium iodide test and after contact with the plants, then no ozone reaction was obtained, thus supporting the statement of Cloez.

In experiments of the kind just described, care must be taken not to employ plants of an aromatic nature, since, as will be afterwards explained, peroxide of hydrogen is certainly produced by them. As plant life, therefore, does not seem to generate atmospheric ozone, its source must be looked for elsewhere.

Now, as in the laboratory ozone is most easily prepared by the action of electrical discharges upon oxygen or air, and as electrical discharges are constantly occurring in the atmosphere, it is most probable that we shall find in this fact the explanation we are looking for. Moreover, there are numerous sources of atmospheric electricity. Of course, in storms attended with lightning, there is the strongest reason for believing that ozone must necessarily be produced, and peroxide of hydrogen also.

A. Houzeau found† that country air contained a maximum of $\frac{1}{450000}$th of its weight, or $\frac{1}{700000}$th of its bulk of ozone, and considered it to be produced

* *Compt. Rend.*, lxxviii., 362.

† *Compt. Rend.*, March 11th, 1872.

by atmospheric electricity constantly acting in the manner of a huge-sized condenser between the soil and the clouds.

It is very probable that the friction of waterdrops as they fall in the form of rain against the air produces negative electricity, as it is also certain that the spray of a fountain, waterfall, or cascade, likewise charges the surrounding air with negative electricity, which, acting upon the oxygen of the air, gives rise, in all probability, to the formation of ozone. That this is so is supported by various experiences which have been summarised by Bellucci in a most interesting paper.* In this communication he points out:—

1. Lender noticed an ozone reaction in the air near the columns where the concentration of brine is carried out at Kissingen; the air, there, is filled with the spray of the salt-water.

2. Gorup-Besanez found that a similar reaction could be observed with the spray of water containing no salt, and that the ozone formed by a spray of water issuing under pressure was greater the more rapid the evaporation.

3. Morin and Monte also found that ozone is produced during the pulverisation of water.

4. The author (Bellucci) observed at Terni, near the falls, a similar ozone reaction, and concluded that it is traceable to the electrical state induced by friction of the minute waterdrops.

Now, if it be true that the friction of waterdrops

* *Gaz. Chimica Italiana*, vi., 88-97.

against the air is sufficient to give rise to ozone, then how great must be the quantity produced over the surface of the oceans! Thus, after all, it may be that sea-air above is in ozone. At the same time it must be remembered that the fact has not been demonstrated by unequivocal tests.

It may, in concluding this part of the subject, be asserted, then, that ozone is a tolerably constant ingredient of pure air, although never present except in traces. The amount of it present in different places is extremely variable, as its production is dependent upon conditions not always in force, and, further, since it is readily destroyed by oxidisable matters generally, and particularly by organic matter in a state of change or decomposition.

In the laboratory, ozone is prepared by the action of electricity upon air or oxygen. Andrews and Tait found that, to produce the maximum amount of ozone, it is best to transmit the electrical discharge silently, as the passage of the spark itself destroys a quantity of the ozone previously formed. Or, as Siemens first showed, ozone may be obtained by submitting a current of oxygen to the action of induced electricity. It forms no part of the present work to describe the different arrangements of apparatus for preparing ozone. Many of these have been described by Dr. Fox in his work on ozone, while all of them are constructed upon the principles stated above. We pass on, therefore, to consider the properties of ozone.

In its natural state, ozone is a gas of greater

density than oxygen, so that a given amount of it occupies a less volume than that of the oxygen from which it is made. Indeed, the preparation of ozone from oxygen may for purpose of illustration be thus written:—$3O_2 = 2O_3$. That is to say, three volumes of ordinary oxygen become, under the influence of electrical action, transformed into two volumes of ozone. At temperatures a little above the boiling point of water, ozone is slowly retransformed into oxygen, and this change is instantaneous at 300°C. With the change back into oxygen, there is an increase of volume exactly corresponding to the diminution observed when oxygen is converted into ozone; and, of course, all the ozonic properties are simultaneously lost, being substituted by those of ordinary oxygen.

There still seems to be some doubt as to the solubility of ozone in water. Most books state that ozone is quite insoluble in water, while Soret stated that water absorbs a certain amount of ozone. This statement of Soret has been confirmed by L. Carius,* who passed ozone (obtained from the electrolysis of a large surface of dilute sulphuric acid at 0°C.) through water maintained at 2° to 4°C., and found that in this way the water absorbed about 4 or 5cc. of ozone. He also found an "ozonised water" sold in Germany to contain a similar quantity of ozone, and to be quite free from peroxide of hydrogen. On the other hand, C. Rammelsberg† found that it

* *Phil. Mag.*, (4) xliv. 544.

† *Deut. Chem. Ges. Ber.*, vi., 603-605.

contained 0·16 per cent. active chlorine (which would give the same reaction with potassic iodide, as that by which Carius estimated his ozone), and that such a product could be obtained by passing air first through a solution of bleaching powder (chloride of lime), and then into water. In all his experiments made with a view of obtaining true ozonised water, he failed.

Em. Schöne,* however, experimenting with ozone got by the silent discharge method, found that ozone is soluble in water to the extent of about 8·81cc. ozone per litre, and that no peroxide of hydrogen is formed by action of the ozone upon the water.

Air highly charged with ozone exerts an irritating effect upon the respiratory organs; and when an excess of ozone is breathed, certain symptoms reminding of catarrhal and bronchial affections are induced. This is not surprising, for even pure oxygen cannot be breathed with impunity, and, naturally, ozone must exercise in the system a much more powerful action than ordinary oxygen. Of course it will be readily understood that these facts express the pathological rather than the physiological properties of ozone, and they are only true of an excess of ozone,—such an excess, indeed, as can never occur in nature.

The idea that ozone is naturally generated in the blood through an action exerted by the red corpuscles upon oxygen, is one which does not rest upon a satisfactory basis.

* *Deut. Chem. Ges. Ber.*, vi., 1208 and 1224-1230.

Ozone exhibits powerful bleaching powers, and converts blue indigo into colourless isatin; curiously enough, however, it seems to have little action upon the colour of flowers, a fact pointed out by A. R. Leeds,* and noted by him as an economical feature in "nature's purifier and disinfectant."

The oxidising effects of ozone are very powerful, and are exhibited even towards such metals as silver and mercury: silver becomes peroxidised under its influence, whereas this metal is not at all affected by oxygen. Ozone also oxidises iodide of potassium, setting free the iodine from its solution; and it is by this reaction that the estimation of ozone is most readily effected. There are easy chemical methods by which free iodine can be estimated; hence, when ozone is present in sufficient amount, nothing is easier than its determination by estimating the iodine set free by it. If the quantity be too small, it can be judged of by the depth of colour it imparts to a paper previously steeped in a mixture of iodide of potassium and starch. Unfortunately, however, other chemical principles act upon potassic iodide in the same way, and thus experiments of this kind, except under special circumstances,—as, for instance, when the substance is known to be pure ozone,—are of little conclusive value.

The oxidising effects of ozone are also readily demonstrated by the ease with which it deodorises putrid

* *Chem. News*, vol. xxxviii., pp. 224, 235, 249, 257.

meat and effusions. Thus, in 1854 Drs. Wood and Richardson * exposed a pint of coagulated ox blood to the air for a whole twelvemonth, by which time the mass had become a most offensive fluid. In 1862, and when it was still most horribly offensive, it was subjected to a current of ozone generated by Siemens' apparatus. By this means the evil odour was gradually and entirely removed, and the resulting product was perfectly sweet to smell.

Schönbein also observed † that "air containing only $\frac{1}{3,240,000}$ of ozone has the power of disinfecting its own volume of air loaded with the effluvia emitted in one minute from four ounces of flesh in a highly putrid state."

A. Boillot ‡ has further noticed that fresh beef was preserved in ozonised air for more than ten days, while in ordinary air a part of the same beef went bad in five days.

The experiments described by Schönbein and the views that he expressed, led chemists generally to believe that nearly all slow processes of oxidation are attended with the production of ozone. By the expression "slow processes," it is intended to indicate the chemical changes that result when such substances as turpentine, ether, and phosphorus are exposed to the air, or to air and water.

I have made the atmospheric oxidation of turpentine and other similar substances a special study for

* See Fox's work on Ozone, p. 30.

† *Ibid.*, p. 94.

‡ *Compt. Rend.*, lxxxi., 1258.

many years, but this is a subject which, from its nature and extent, demands exhaustive treatment in a special chapter.

As regards the slow oxidation of the ethers, this is also a matter which I have studied to some extent, and although the research is far from complete, I have ascertained that ozone never results from such reactions. On the other hand, the process never failed to yield peroxide of hydrogen, exhibiting all its well-known reactions and qualities.* More recently, M. Berthelot has stated that when ether is exposed to the action of ozone there is obtained a peculiar compound which he styles "ozonised ether," and this, when shaken with water, produces peroxide of hydrogen.†

In the first edition of this book, I had to give expression to the doubts that then existed concerning the supposed production of ozone by the aërial oxidation of phosphorus, and reasons were stated why peroxide of hydrogen might be expected to result from the process. Since then the whole subject has been very carefully studied, and in a report‡ which I had the honour of presenting to the Chemical Society late in 1880, an account is given of my own researches and those of others, notably the investigation conducted simultaneously by Dr. A. R. Leeds. It is now quite certain that when phosphorus is partially submerged in water and exposed to a

* *Chem. News*, vol. xxxiv., p. 135.

† *Compt. Rend.*, lxxxvi., 71-76.

‡ *Journ. Chem. Soc. Trans.*, 1880, p. 792.

current of air, both ozone and peroxide of hydrogen are produced in considerable amount. The ozone is carried off in the current of air, and the peroxide of hydrogen dissolves in the water in which the phosphorus is placed.

The manner in which these facts were ascertained may be briefly described in this place.

The apparatus used in my experiments was specially constructed for the purpose, and consisted of a number of wide-mouthed bottles, each of 300cc. capacity, and provided with well-fitting solid stoppers having two apertures. In these apertures with ground surfaces I placed tubes which were enlarged and ground at the requisite positions, so that when they were fitted into their proper places, the joints were perfectly tight, and could be easily disconnected or renewed. This special form of apparatus was adopted in order to avoid the use of oxidisable materials in the construction of the joints, and it is apparent that a perfect battery of such oxidisers could be used, the tubes of the various members being connected in the manner described by the late Sir Benjamin Brodie, by means of paraffin.

In each of five such oxidisers there was placed a stick of phosphorus, scraped clean just before use, and then sufficient water to half submerge the phosphorus, leaving the other half exposed to the air in the bottles. The sixth vessel was charged with 200cc. water, to serve as a wash-bottle, and then the series was connected together, and a current of air previously filtered through cotton-wool and washed

in water, was in each experiment blown through by means of a rotating fan.

Operating thus, it was found that the air which had passed over the phosphorus contained ozone, which substance was identified in a thoroughly satisfactory manner. It possessed the characteristic odour of that principle: it was entirely absorbed by oil of turpentine, and was destroyed at a temperature of 240°C. It liberated iodine from an acidified solution of potassic iodide, and by determining the iodine thus set free, the amount of the ozone was ascertained.

The presence of peroxide of hydrogen in the water in which the phosphorus was partially submerged, was proved also by a practical examination, in which it was found that the solution could be concentrated by evaporation, and it gave all the qualitative and quantitative reactions which will be described in greater detail when we come to describe that substance and its properties.

Nitrogen.

Symbol N. Atomic Weight 14.

Nitrogen constitutes the larger proportion of the atmosphere, and may be prepared in the pure state, among other methods, by the combustion of phosphorus in a vessel containing air standing over water. The phosphorus burns at the expense of the oxygen with which it enters into combination, leaving nearly pure nitrogen gas behind. It is colourless, tasteless, and inodorous, and almost insoluble in water. At an

extremely low temperature and when subjected to a great pressure it liquefies, in common with hydrogen and oxygen gases.

While nitrogen cannot be described as a poisonous gas, it has no power to maintain life; on the other hand, when breathed in the pure state it destroys life, for the same reason that it cannot sustain combustion, viz., because it puts an end, for want of oxygen, to both processes, which are, as we have seen, dependent upon active oxidation.

In respiration, nitrogen is not assimilated by the blood as oxygen is, but is expired in the breath. Notwithstanding this, it enters very largely into the composition of animal and vegetable tissues, being obtained in the human body from the nitrogenous constituents of the food. It also occurs in the mineral world in the state of nitrates of sodium, potassium, and calcium.

The production of nitrates in soils is of a continuous character and proceeds more actively in the hotter climates. The manner of their formation is extremely interesting, and the recently conducted investigations of MM. Schlœsing and Muntz, in France, and of Mr. Robert Warrington in this country, have led to some important discoveries. It is now known that "nitrification" is due to the action of living ferments which cause the oxidation, in the soil, of ammonia and the nitrogen of organic bodies. If a small quantity of fresh soil be added to a dilute solution of urine, active nitrification is induced, and the ammonia or urea is converted into a nitrate. It is

necessary for the production of nitric acid in this way that some base should be present wherewith it may enter into combination. The solution of urine, nitrified as above described, then possesses the power to induce the process in other solutions of urine. These facts are comparable with the more widely known and better understood features of alcoholic fermentation, in which, as a correlative phenomenon of a vital act, sugar is converted into alcohol.

The production of nitre on the artificial plan has for a long period been carried on in Europe. Mould, rich in nitrogenous matter, is formed into heaps of a porous character, so as to allow free admission of air, and treated from time to time with urine and water in regulated quantities. After two years of such treatment, care being taken to protect the heaps from rain, they become sufficiently rich in nitrates to be worth extracting. The chief nitrate thus formed is nitrate of calcium, the potassium salt being made from it by treatment with wood ashes or with carbonate of potassium. In this way about 5 lbs. of nitre can be obtained from each 1,000 lbs. of the nitrified soil. It is worthy of remark that it is from nitrates present in the soil that plants, in the main, derive their nitrogen, and thus we can appreciate the importance of nitrates from a manurial point of view, or, what is equivalent thereto, the importance of using nitrogenous manures.*

* See Mr. Warrington's paper read before the Society of Arts, vol. xxx., p. 532.

At present our knowledge concerning nitrogen as the chief constituent of the atmosphere, and its natural relations, is of a very limited character. There is no proof that the nitrogen of the air contributes in any way towards the formation of nitrates in the soil, and the extent to which free nitrogen is contributed to the air by animal and vegetable matters in a state of decay or putrefaction has not been accurately ascertained. It is known, however, that in ordinary putrefaction some nitrogen gas is evolved, and that an abundance of oxygen causes the evolution of much nitrogen; indeed, it then becomes the principal gas.

Combustion of nitrogenous organic matters also gives rise to the production of some free nitrogen.

Carbonic Anhydride (Carbonic Di-oxide; Carbonic Acid).

Formula CO_2. *Molecular Weight* 44.

Carbonic anhydride is a constant constituent of the atmosphere, although its proportion differs with place and time, varying from 2 to 10 parts in 10,000 of air. The amount present in the air is greater in summer than in winter; it increases during the night, and decreases after sunrise. It is given off from the human body as an excretory product in the breath, and it is formed by the slow decay, as also by the rapid combustion of organic matters generally. Carbonic anhydride is decomposed by the leaves and other green parts of plants, but the decomposition takes place only during daylight, and to the greatest

extent during bright sunshine. In this process oxygen gas is set free, and the carbon is taken up by the plants in some manner at present imperfectly understood. During darkness, plants evolve carbonic anhydride, and this may account for the increased amount of that substance which is found present in the atmosphere by night.

The quantity of carbonic anhydride contained in the air of houses and closed inhabited spaces, is in excess of the amount found in the open air, and one of the objects of ventilation is to reduce the amount as far as possible.

In the laboratory, carbonic anhydride is best prepared by acting upon marble with hydrochloric acid, as illustrated by the following chemical equation :—

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

Carbonic anhydride (carbonic dioxide) is a colourless inodorous gas, which can be readily reduced to the liquid and solid states. It is about 1·5 times heavier than air, and is soluble in water to a very considerable extent; one volume of water at 0°C. dissolves 1·797 volumes, but at 20° the quantity dissolved is only 0·901 volume.

When present in the air in any considerable proportion it acts as a poison, as will be more fully explained in the chapter on Respiration. On account of its poisonous effect, fuel (of any kind) should never be burned in rooms except in fireplaces connected with efficient chimneys, and since it constitutes one of the products of burning gas, the further

necessity of efficiently ventilating dwelling apartments is at once apparent.

Although air only contains on the average 4 volumes of carbonic dioxide in 10,000 volumes, the absolute amount thus presented in nature is enormous, as may be readily proved by calculation. It also occurs in the air of mines and old wells, and is commonly known as "choke-damp." Common chalk and marble are compounds of carbonic dioxide with lime (carbonate of calcium, $CaCO_3$).

Soda-water of commerce is an aqueous solution mechanically charged with a large amount of carbonic anhydride, and it is this gas which escapes so briskly when the cork is removed from bottles containing the fluid.

Spring water is often charged with carbonic anhydride, derived from the gradual oxidation of vegetable organic matters held in solution by the action of the air, and it is to the presence of this gas that part of the so-called "hardness" of water is due.

Hydrogen.

Symbol H. Atomic Weight 1.

In 1766, Cavendish first obtained "hydrogen" gas by the action of sulphuric acid upon zinc, thus,

$$Zn + H_2SO_4 = Zn\,SO_4 + 2H.$$

and upon examining its properties, he found that if mixed with ordinary air, and the mixture was exposed to a flame, it exploded, producing moisture. But it was not until after Priestley had made oxygen that

he became fully aware of the fact that the explosion referred to was owing to the combination of hydrogen with oxygen. He repeated his experiments with pure oxygen, and thus formed water.

The combination referred to, may be expressed as follows :—

$$H_2 + O = H_2O.$$

Hydrogen is the lightest body in nature, being fourteen and a half times lighter than air, but notwithstanding this, it has of late years been reduced to the liquid state, as already mentioned.

Its properties do not call for any extensive treatment in this place, since it is only important, in connection with the subject of this volume, as a constituent of water and peroxide of hydrogen.

Hydrogen gas is combustible, and when it is burned in the air or in oxygen it enters into combination with the oxygen, and water is the product. This reaction is remarkable in so far as it illustrates the direct formation of a liquid substance by the chemical combination of two gases.

Hydrogen is not poisonous in the ordinary sense of that expression, although of course it cannot support life. In this sense it resembles nitrogen.

Water.

Formula H_2O. *Molecular Weight* 18.

The occurrence of water in nature and its general properties are matters of such common knowledge that it is altogether unnecessary to dwell upon them.

It is important, however, to bear in mind that it exists in the air in the dissolved state, a matter to which more particular reference will be made hereafter.

Water is always produced by the combustion of organic substances containing hydrogen, and it accompanies carbonic anhydride as a product of respiration. As its formula implies, it is a combination of two volumes of hydrogen with one volume of oxygen. It may be described as a perfectly neutral substance, exhibiting no active characters and possessing no power as an oxidising agent, although every 18 parts by weight contain 16 parts of oxygen. All its oxygen is utilised, so to speak, in retaining the hydrogen in combination, and in this respect it is widely different from peroxide of hydrogen or chemically oxygenated water, which is the substance that will be next considered.

Water plays an important part as an atmospheric constituent, inasmuch as it acts as a screen in preventing radiation of heat from the earth. In this direction the recent observations made by Tyndall are of special interest. In the forms of ice and steam its uses and properties are of the most important order and perfectly well understood. It is indispensable to animal and vegetable life, and it enters very largely into the composition of animal and vegetable substances, even to the extent of from eighty to ninety per cent.

As a potable substance we shall deal with it hereafter.

Peroxide of Hydrogen (Hydric Di-oxide).

Formula H_2O_2. Molecular Weight 34.

This substance was discovered by Thenard in 1818. He obtained it by acting upon barium dioxide with dilute hydrochloric acid, thus:—

$$BaO_2 + 2HCl = BaCl_2 + H_2O_2.$$

In many of its properties it resembles ozone, and is, indeed, formed together with it in the electrolysis of acidulated water. When water is electrolysed, the theoretical amount of oxygen that should be obtained according to the equation $H_2O = H_2 + O$ is not yielded; there is a slight deficiency, and it is this missing quantity which goes to form peroxide of hydrogen by combination with water.

Peroxide of hydrogen differs essentially from ozone and oxygen in being a liquid at the ordinary temperature and pressure of the atmosphere. Moreover, whereas ozone is a gas which is very slightly soluble in water, peroxide of hydrogen is extremely soluble in water.

It is seen from what has preceded that the composition of these two substances is perfectly distinct, but some years ago their chemical nature was less clearly understood; hence some of the confused ideas that still prevail. F. Le Blanc * believes that the peroxide of hydrogen which is produced during the electrolysis of acidulated water is due to the

* *Compt. Rend.*, lxxv., 537.

action of ozone upon the water. This, however, is very improbable, and while there is no evidence in favour of the notion, Schöne has expressly satisfied himself to the contrary by careful experiments.

It may be prepared by suspending baric dioxide in water and passing a current of carbonic dioxide gas through the mixture. The following equation represents the changes which occur:—

$$BaO_2 + H_2O + CO_2 = BaCO_3 + H_2O_2.$$

That is to say, the carbonic anhydride unites with baryta to form the insoluble carbonate, whilst the second atom of oxygen in the dioxide of barium unites with the water to form the hydric peroxide.

As made in this way, the peroxide is very dilute, so that for all practical purposes it is better obtained by treating the peroxide of barium suspended in water with the theoretical amount of dilute sulphuric acid required to fully react upon it, as follows:—

$$BaO_2 + H_2SO_4 = BaSO_4 + H_2O_2,$$

or, as better shown:—

$$BaOO + H_2OSO_3 = BaOSO_3 + H_2OO.$$

The sulphate of barium forms a white insoluble precipitate, while the peroxide of hydrogen passes into solution at once.

For commercial uses, it is prepared by a similar process to that just described, only in the place of sulphuric acid, hydrofluoric acid or hydro-fluosilicic acid is used, and either insoluble fluoride or fluo-

silicate of barium is formed, peroxide of hydrogen alone remaining in solution.

The occurrence of peroxide of hydrogen in nature, until quite recently, attracted but little attention, and this is not surprising if it be reflected that there were but slight means of distinguishing between it and ozone. Moreover, many of the natural processes now well known to generate peroxide of hydrogen were up to the last few years regarded exclusively as sources of ozone. In fact, peroxide of hydrogen, giving the same tests, was mistaken for ozone.

Not only Schönbein and Dumas thought it probable that peroxide of hydrogen should occur in the atmosphere under certain circumstances more guessed at than determined, but Prof. Struve* claimed, in 1869, to have demonstrated its presence in the air as a product of simultaneous formation with ozone, and stated that the colouring of iodized starch paper when exposed to the atmosphere, is the joint result of the influences of ozone and peroxide of hydrogen. He also pointed out that peroxide of hydrogen may be condensed in rain-water.

Since that time, much attention has been given to this subject by various observers, and particularly so, since I discovered that all kinds of aromatic plants produce peroxide of hydrogen liberally. The way in which they do this, is reserved for special treatment in a separate chapter, and here, the mere statement

* *Compt. Rend.*, 1869.

may be submitted, that probably all plants and flowers of perfume (at least all those which are known to secrete essential oils) generate peroxide of hydrogen into the atmosphere, by the joint or successive action of air and water upon the said oils and perfumes.

Em. Schöne * found more peroxide of hydrogen in a litre of dew or hoar-frost during the summer months than during the winter months. In a lecture-hall which had been closed for some weeks, he also found about 0.17cc. peroxide of hydrogen (H_2O_2) in 1,000 cubic metres of air.

It will be understood that, as peroxide of hydrogen is abundantly soluble in water, its presence in rain-water or dew is not at all surprising. As the rain or waterdrops fall through or condense from the air containing the peroxide of hydrogen, this substance, of course, dissolves in the water.

In a subsequent investigation † Schöne found that "the higher above the earth's surface the condensation of atmospheric aqueous vapour takes place, the richer in peroxide of hydrogen is the resulting precipitate." This also is quite intelligible, since peroxide of hydrogen, like ozone, is unstable, and is readily decomposed by organic matters generally, which matters are most abundant near the earth's surface.

Then again, Schöne finds ‡ that in the strata of

* *Ber. Deut. Chem. Ges.*, No. 6, 1878.
† *Ibid.*, No. 8, 1878.
‡ *Ibid.*, No. 9, 1878.

the atmosphere accessible to investigation, the peroxide of hydrogen is greater, the higher the sun rises above the horizon, both during the day and the year, and the smaller the obstructions to the sun's rays. He considers, therefore, that the amount of peroxide of hydrogen should notably increase towards the equator. This consideration is very probably a correct one, for in the tropical regions, vegetation abounds most freely; and there it is that we meet with the greatest known source of peroxide of hydrogen. In those huge areas of vegetable life, every oil-secreting tree or plant is giving rise to the production of peroxide of hydrogen as before mentioned.

M. Sergius Kern, following up the experiments of Schöne, has more fully examined rain-waters,* and he finds that equatorial winds bring rains much richer in peroxide of hydrogen than the rains carried by polar winds, thus lending confirmation to the above-expressed views.

Further, it has been pointed out by A. R. Leeds † that papers which have been moistened with potassic iodide and starch (Osann's test-papers) are not generally coloured at Hoboken, but only tinted on rare occasions. On the other hand, in Keene Flats, N.Y., the days were few on which no indication was obtained. It should be stated that the place of investigation in Keene Flats was 700 feet above

* *Chem. News*, vol. xxxvii., p. 34.

† *Ibid.*, vol. xxxviii., pp. 224, 235, 249, 257.

the sea level, and the surrounding vegetation was chiefly deciduous. At a point near the upper end of Upper Saranac Lake, which is even at a much greater altitude and surrounded with miles of primitive forestry embracing hemlocks, pines, larches, and spruces, the woods being often redolent with balsamic odours and extensively used as a health resort by large numbers of patients, Mr. Leeds found the most intense and frequent reaction with the test-paper. Although, in his published papers, he assumes this active constituent of the air to be ozone, the test employed, as already explained, is one equally sensitive to peroxide of hydrogen, whose very home is forestry embracing pines and spruces. It is certain, indeed, that the coloration of the test-paper was due to peroxide of hydrogen.*

M. J. Clermont † avers that he has detected the presence of peroxide of hydrogen in the juices of many bruised plants, such as the tobacco plant, the vine, lettuce, etc. The test, however, which he employed is just as characteristic of nitrites (which are far more likely to be present) as it is of peroxide of hydrogen. His statement having received no kind of confirmation, and a direct refutation at the hands of Prof. G. Bellucci, ‡ it may be dismissed as erroneous.

S. Cohné § has described some few simple experi-

* *Chem. News*, vol. xxxviii., p. 243 (critical note by the author).

† *Compt. Rend.*, No. 25, June 28th, 1875.

‡ *Gaz. Chim. Ital.*, Anno viii., 1878. Fasc. vii. and viii.

§ *Chem. News*, vol. xxxiv., p. 4.

ments which, according to his interpretation, go to show that certain parts of plants, by contact with peroxide of hydrogen, give rise to ozone. In the same journal * I have critically examined Cohné's experiments, and have shown that his results admit of another and more plausible explanation. Peroxide of hydrogen, even in dilute solutions, undergoes slow spontaneous decomposition into water and free oxygen, and this decomposition is accelerated by contact with many substances. For instance, meat fibrin exhibits this contact-power in a remarkable degree; and it is not improbable that the fibrin of plants possesses a similar power, more particularly since, as Cohné himself shows, a stem is most active where it has been cut through. Now, in such a decomposition of peroxide of hydrogen, the oxygen escapes from a solution which is known to react with the test-mixture employed, and as the bubbles of gas escape from the fluid, they are probably saturated with the peroxide of hydrogen, just as ordinary air contains moisture. It is this escaping hydric peroxide (which might also be carried up as spray) that Cohné evidently mistook for ozone. Thus, there is as yet no kind of proof either that ozone in the presence of water yields peroxide of hydrogen, or that peroxide of hydrogen can give rise to ozone.

Nevertheless, A. Houzeau † thinks that in certain cases—for instance, when ozone acts upon sulph-

* *Chem. News*, vol. xxxiv., p. 20.

† *Compt. Rend.*, lxxv 349-351.

indigotic acid—peroxide of hydrogen is intermediately formed in solution. This is by no means improbable; indeed, it is certain that other processes of oxidation also give rise to peroxide of hydrogen, both intermediately and finally. Thus, P. Schützenberger, in the course of some interesting experiments,* obtained results which led him to the conclusion that peroxide of hydrogen is intermediately produced by the action of air or oxygen upon hyposulphite of sodium. It is also formed as a final product of the atmospheric oxidation of that class of hydrocarbons known as terpenes, and of which turpentine is illustrative.

Having now briefly considered the various processes by which peroxide of hydrogen is formed, we may examine its nature and more important reactions.

It has been stated (in an earlier chapter) that water was found by Cavendish to consist of hydrogen in combination with oxygen. In other words, two volumes, or atoms, of hydrogen, when exploded with one atom or volume of oxygen, combine and form one molecule (two volumes) of water:—

$$H_2 + O = H_2O.$$

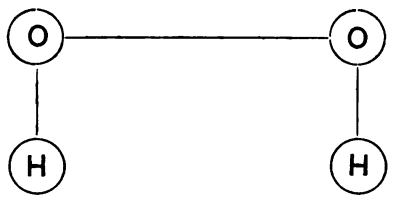
Now, peroxide of hydrogen contains one more atom or volume of oxygen than does water in its molecule, and so it is represented by the formula H_2O_2.

It is this additional atom of oxygen that gives

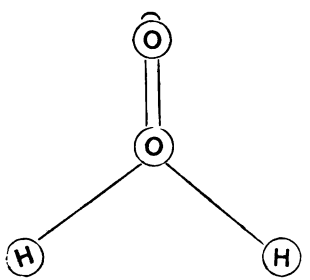
* *Bulletin de la Société Chim. de Paris*, vol. xx., p. 145. 1873.

to peroxide of hydrogen its important character as an oxidising agent.

The constitution of peroxide of hydrogen is not thoroughly understood. Generally, the constitution is structurally represented in this manner—



which would signify that each atom of oxygen (here regarded as a dyad in atomicity) is directly combined with the other atom of oxygen, and with one atom of hydrogen. Such a formula fails altogether to explain the oxidising effects of the substance, and in my opinion it is to be regarded not so much as a peroxide of hydrogen in the strictly chemical sense, as an oxide of water, or oxygenated water. If my view be correct, then the constitution of peroxide of hydrogen may be represented thus:—



Here, oxygen is represented as a tetrad in atomicity; the one atom is directly combined with two atoms of hydrogen, as in water; whereas the second atom of oxygen is combined only with oxygen, thus readily accounting for the best known properties of the substance. My view * is supported by certain observations made by M. Berthelot.† He has shown that, the oxygen set free when oxide of silver reacts upon peroxide of hydrogen, is only equal in amount to that present in the oxygenated water, the residual matter containing the whole of the silver and oxygen originally contained in the oxide of silver employed; but there is a redistribution of the elements, so that in reality the residual mass is a mechanical mixture containing one-third of the silver in the reduced (metallic) state, and the corresponding portion of oxygen as sesquioxide of silver. In other words, the reaction is not to be represented by the equation

$$H_2O, O + Ag_2O = H_2O + Ag_2 + O_2,$$

but by

$$3\,H_2O, O + 3\,Ag_2O = 3\,H_2O + Ag\,O_3 + Ag_2 + O_3.$$

By careful concentration of a dilute aqueous solution of hydric dioxide *in vacuo* at low temperatures, it may be obtained in the form of a syrup which is colourless and has a faint odour reminding both of chlorine and ozone. This fluid is, however, very unstable, and slowly undergoes decomposition, even at ordinary temperatures, as follows:—

$$H_2O_2 = H_2O + O,$$

* *Chem. News*, vol. xlvi., 141.

† *Compt. Rend.*, 90, 572—577.

the oxygen gas escaping in the form of minute bubbles. This decomposition is assisted by the presence of many substances (notably alkalies), and particularly of those which are themselves in a state of change or decomposition. On the other hand, the presence of a little ordinary ether restrains the decomposition; and not unlikely the reason for this is to be found in the fact elsewhere noticed, that ether itself gives rise to the production of peroxide of hydrogen by contact with air or oxygen and water.

If the syrupy solution of peroxide of hydrogen be heated to the boiling point of water, it suddenly decomposes, and the oxygen escapes with explosive violence.

The liquid is miscible with water in all proportions, and it is generally stated in books that, although dilute solutions are more stable than strong ones, yet even dilute solutions are immediately decomposed on ebullition. Indeed, this method has been advocated as a good means of estimating the strength of the peroxide of hydrogen by measuring the evolved gas. Experience does not bear out this statement. Early in my researches on the oxidation of the essential oils of plants, there was occasion to compare the properties of peroxide of hydrogen with some of the products obtained in the experiments, and it was then found* that not only might dilute solutions of peroxide of hydrogen be boiled for some minutes without any appreciable decomposition, but that the

* *Journ. Chem. Soc. Trans.*, 1874, p. 14.

presence of a quantity of chloride of zinc did not increase the amount of change. Mr. G. E. Davis has since obtained similar results,* and finds that a dilute solution may be concentrated, by evaporation, to half its bulk without driving off more than two-thirds of its active oxygen.

To illustrate the rate of decomposition of solutions as kept in the laboratory, Mr. Davis's figures may be quoted. The solution he operated upon was what is known as a "10 volume" one; that is to say, it was a solution capable of evolving ten times its own volume of gaseous oxygen when fully decomposed. Thus, 100cc. would evolve 1000cc. oxygen; in other words, it would contain 3·04 per cent., by weight, of peroxide of hydrogen (H_2O_2), and evolve 1·43 per cent. oxygen by weight:—

On August	2nd,	1878,	the	strength	of	the solution was 9	volumes.
,,	9th,	,,	,,	,,	,,	8·4	,,
,,	24th,	,,	,,	,,	,,	8·0	,,
Sept.	1st,	,,	,,	,,	,,	7·9	,,
,,	24th,	,,	,,	,,	,,	7·8	,,
Oct.	24th,	,,	,,	,,	,,	7·2	,,

By adding a few drops of ether, this strength was maintained, for on testing two months later it was found to be the same as on October 24th.

Dilute solutions of peroxide of hydrogen, then, are tolerably stable, and particularly if they be of slightly acid reaction; if, however, they be alkaline, owing to the presence of traces of soda, potash, or ammonia, then they are much less stable, and particularly

* *Chem. News*, vol. xxxix., p. 221.

evince a tendency to decompose entirely upon heating. An alkaline solution of peroxide of hydrogen is partially decomposed by mere agitation, and the statement has been made that agitation with air is sufficient to entirely decompose even pure peroxide of hydrogen in course of time. Mr. Davis does not corroborate this result, and, indeed, finds that by the passage of fifteen cubic feet of air per twenty-four hours through a dilute solution, no peroxide is destroyed; but, on the other hand, he has found at the end of the experiment an excess, even in the presence of caustic soda.

Two facts in connection with this last-named circumstance may be cited with interest. One has been pointed out previously, viz., that of the apparently well-ascertained production of peroxide of hydrogen or ozone by friction of waterdrops against atmospheric air. The other fact may have some connection, perhaps, with the possible behaviour of the caustic soda. Cuprous oxide (Cu_2O) shows no tendency to absorb oxygen and pass into cupric oxide (CuO) when it is suspended in water and subjected to a current of air. If, however, the water contains a very minute quantity of caustic soda, then it has been found that cupric oxide begins at once to form,* and goes on increasing until the whole of the red cuprous oxide is converted into the black (higher) oxide.

It is difficult to explain these facts, except on the

* *Chem. News*, January 5th, 1872.

supposition that caustic soda has the power, under the conditions given, to absorb oxygen, and pass temporarily into a higher state of oxidation. From this state it may be immediately reduced to its former condition by the action of the cuprous oxide, which seizes its excess of loosely combined oxygen for itself. No more attention can here be given to this subject, except to remark that, in common with many similarly interesting instances of slow oxidation, it calls for much further study and observation before an absolutely satisfactory explanation can be obtained.

There are several methods by which the strength of pure peroxide of hydrogen may be determined.

1. A given volume is taken and placed in a tube with excess of potassic bichromate; on agitation over mercury a quantity of oxygen gas is evolved, which, supposing 1cc. of the peroxide of hydrogen has been taken, expresses its strength in so many volumes. Thus 1cc. of a 10-volume solution would yield 10cc. of oxygen at 0°C. and 760 mm. Bar.*

2. A given volume of the peroxide is treated in a

* Peroxide of hydrogen furnishes a beautiful reaction with chromic acid, which first of all gives a blue colour with the peroxide of hydrogen; the oxygen is then gradually evolved, the colour fading at the same time:—

$$2CrO_3 + 3H_2O_2 = Cr_2O_3 + 3H_2O + 3O_2.$$

If an excess of peroxide of hydrogen be used in this experiment, then a further reaction occurs, in which the H_2O_2 loses exactly double the amount of oxygen lost by the chromic acid, so that the ultimate result is—

$$2CrO_3 + 6H_2O_2 = Cr_2O_3 + 6H_2O + O_2.$$

measured tube over mercury, with excess of acidified solution of permanganate of potassium, when oxygen gas is instantly evolved, according to the equation :—

$$Mn_2O_7 + 5H_2O_2 = 2MnO + 5H_2O + 5O_2.$$

It will be seen from this equation that only one-half of the evolved oxygen is derived from the peroxide of hydrogen; and if this quantity be corrected for temperature and pressure, it agrees with the result furnished by the next method.*

3. When peroxide of hydrogen is added to a solution of potassic iodide which has been acidulated with pure dilute sulphuric acid, there is a liberation of iodine, which is revealed by the red colour acquired by the solution. The ultimate result of the reaction may be expressed thus :—

$$2KI + H_2SO_4 + H_2O_2 = K_2SO_4 + 2H_2O + I_2.$$

If starch be added to the mixture, the free iodine combines with it to form a splendid blue compound, which by its depth of tint serves to render the determination of the iodine more accurate. This estimation is effected by ascertaining how much hyposulphite of sodium of known strength is required to decolorize the solution thus :—

$$2Na_2S_2O_3 + I_2 = 2NaI + Na_2S_4O_6.$$

Before passing on to other considerations, it must be stated that the action of peroxide of hydrogen upon potassic iodide is by no means instantaneous in

* In illustration of both these methods I have given examples in my papers published in *Journ. Chem. Soc. Trans.*, 1875 (p. 9 of paper), and *Journ. Chem. Soc. Trans.*, 1880 (pp. 10—15 of paper).

character. A certain amount of decomposition occurs at once; but the rest of the decomposition is effected only very slowly, so that often half-an-hour or more is required for its completion. The process is therefore tedious as ordinarily practised, and for many purposes the second method is preferable. I have, however, more recently ascertained that the process may be greatly expedited by the free use of acid, and if a great excess of acid be employed, the decomposition is completed almost immediately, so that the iodine which is liberated may be at once and accurately determined.* In contact with pure potassic iodide, no acid being present, peroxide of hydrogen is resolved into water and oxygen, but iodine is not set free.

The decomposition that occurs between peroxide of hydrogen and permanganate of potassium in the presence of acid is not always explained by chemists in accordance with the equation given above, but in a recent paper † Messrs. Carpenter and Nicholson have confirmed the entire accuracy of the results, not only of my previously conducted study of the same reaction, but also those attending the estimation of peroxide of hydrogen generally.

The other reactions of peroxide of hydrogen are both interesting and numerous; but attention will be confined, in this place, to the more important ones only.

It bleaches litmus and many other vegetable

* See my report in *Journ. Chem. Soc. Trans.*, 1880, p. 802.

† *The Analyst*, vol. ix., p. 36.

colours, and in recent years has been largely employed for bleaching human hair, to which it imparts a golden hue.

It oxidises sulphides, and thus converts black sulphide of lead into the white sulphate:—

$$PbS + 4H_2O_2 = PbSO_4 + 4H_2O.$$

It is decomposed by many metals when these are added to it in a state of fine division: gold, silver, and platinum, all occasion its decomposition in this way without being themselves thereby apparently influenced. This kind of action is well known in chemistry as contact action, but it is at present without a satisfactory explanation.

The oxides of the three metals just named also decompose peroxide of hydrogen; and not only this, but they are themselves thereby reduced to the metallic state. If the peroxide, in a very concentrated state, be allowed to fall, say, upon argentic oxide, this double decomposition is attended with explosive violence, owing to the rapidity with which the large volume of oxygen is liberated.

Peroxide of hydrogen, as we have seen, unless specially protected against such an occurrence, gradually undergoes spontaneous decomposition from the moment of its formation, and immediately that it comes in contact with bodies like argentic oxide, it gives a similar impulse to their molecular constituents, with the consequence of double and accelerated decomposition.

Brodie explained this fact by assuming that the

second atom of oxygen in the hydric peroxide exists in a polar condition different from that of the oxygen in the oxide of silver; consequently, one being negative and the other positive, they exert a mutual tendency to combination, thereby forming a neutral molecule of oxygen.

All such actions and reactions may be explained in a general way which assumes nothing, while it suffices as an explanation. It is this. All substances, as we know and recognise them, exist by virtue of certain fixed conditions; and the more easily these conditions can be influenced from without, the more easily do such substances undergo change. In brief, mechanical, chemical, or any other kind of motion, exerts an influence on the powers which determine the state of a body.

Peroxide of hydrogen is not alone decomposed by metals and their oxides, but by almost every substance which admits of being oxidised. Thus ferrous sulphate is oxidised to ferric sulphate, and sulphuretted hydrogen is decomposed as follows:—

$$H_2O + H_2S = 2H_2O + S.$$

That is to say, water is formed and sulphur is deposited.

Peroxide of hydrogen, prepared by chemical processes, is largely used in commerce for bleaching oils, wax, ivory, tobacco, blood serum, and engravings and paintings. For such purposes, or some of them, it is used after being rendered strongly alkaline by the addition of caustic ammonia.

The therapeutic properties of peroxide of hydrogen will be referred to hereafter.

All animal and vegetable substances in a state of change or decomposition are rapidly acted upon by peroxide of hydrogen, much more vigorously, indeed, than by ordinary air or even pure oxygen; and hereafter we shall see what an important part it plays as a natural disinfectant. It not only exercises a disinfecting action by virtue of its power to give up oxygen to decomposing matters, but it can absolutely arrest decomposition, and is fatal to the micro-organisms that breed putrefaction and various contagious diseases, as will be demonstrated in a later chapter.

CHAPTER III.

THE AIR, RESPIRATION, AND VENTILATION.

THE atmosphere is a mixture of gases, chiefly nitrogen and oxygen. Carbonic dioxide, aqueous vapour, ammonia, nitric acid, ozone, peroxide of hydrogen, and other substances are, or may be, present in small proportions; while in the air of towns are also to be found carburetted hydrogen, sulphuretted hydrogen, and sulphurous anhydride, which substances are derived from the combustion of fuel (coal and coke) containing sulphur. Ignoring, for the moment, the substances that are present in small quantity, the air may be described as a mechanical mixture, containing in each 100 volumes, 79 volumes of nitrogen and 21 volumes of oxygen.

The amount of water vapour present in the air varies with the latitude and season, and is chiefly dependent upon temperature. It is present in a dissolved condition in the other gases. Dry air always retains the gaseous form, but aqueous vapour is not permanent, and this fact accounts for considerable variations in the composition of the atmosphere. The circulation of the air constantly exposes it to fresh conditions; at one time a part

of the aqueous vapour may be precipitated as dew, or absorbed by dry tracts of land; and at other times an additional quantity may be assimilated from rain, or from the ocean, or moist surfaces of land. The density of the air consequently depends in part on the ratio of its contained aqueous vapour.

A cubic foot of air weighs at 60° F. and 30 metres Bar., 536·96 grains, but its density is supposed to diminish as we recede from the earth, which it surrounds as an atmospheric envelope to a calculated height of about 45 miles. We are enabled to register the constantly varying pressure of the atmosphere at the surface of the earth by means of the barometer.

The average composition of the atmosphere in this climate is expressed in the following table:—

Oxygen	20·61
Nitrogen	77·95
Aqueous vapour . . .	1·41
Carbonic Anhydride . . .	·04
	in 100·00 volumes.

It is upon the oxygen which is contained in air that animal life depends, supporting as it does the process of respiration. It is also of great importance to plants, to which it is carried by the solvent action of water.

Some, at least, of the ammonia which is found present in the atmosphere and upon nearly all articles exposed to the air, even to the furniture of dwelling-houses, is produced by the decomposition of organic matter which is constantly taking place. This fact

formed the subject of many interesting speculations and practical observations by the late Dr. R. Angus Smith,* and, indeed, he attempted to make the ammonia detected upon exposed surfaces, serve as the measure of organic matter present also. Not only is ammonia derived from all living organisms, but it results also from the decay of all vegetable and animal matters; being volatile, it escapes into, and can always be detected in, the air, and generally in all water supplies also. "A room that has a smell indicating recent residence will, in a certain time, have its objects covered with organic matter, and this will be indicated by ammonia on the surface of objects." "When a room is shut up even for a day, unless the room be very large indeed, there is always that peculiarity observed by sensitive persons to which there is given the name of closeness. To me," Dr. Angus Smith continues, "it seemed perfectly clear that the character of closeness was connected with the existence of organic matter, and the organic matter with the ammonia." Oxygen, as contained in the air, removes this closeness by oxidising the organic matter freely, the gaseous products being carried away in the currents of air which we admit into our dwelling rooms with the very object of getting rid of the closeness. The precise mode of action of the atmospheric oxygen involved in this process and that of purification generally will be dealt with hereafter.

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* See *Sanitary Record*, Oct. 15th, 1883.

It will suffice in this place to state that oxygen in one form or another is the great purifier that nature has provided for cleansing the air, the earth, the waters that are on the face of the earth, and all things that are in our houses and upon our bodies, from impurities that are associated with disease, and the micro-organisms that in some instances give rise to it. No matter how concentrated the organic matter or disease-producing filth, oxygen is all-powerful, if time and sufficient quantity be employed, to rob these matters and the very germs of disease themselves, of their power for evil, and even to transform them by oxidation into innocuous and useful products.

No better example of the beneficent action of atmospheric oxygen can be taken than that afforded in the process of respiration.

This process is of such high importance in relation to health, that we must now consider it somewhat in detail. By the action of the heart the blood is pumped through the lungs at a rate which has been variously estimated as equal to from 10 lbs. to 27 lbs. in one minute. The blood thus conveyed into the pulmonary capillaries is venous in character; that is to say, it is dark in colour and is charged with carbonic anhydride, which it has collected throughout the system as a product of the oxidation which is continually taking place within our bodies. This carbonic anhydride is an excretory product, and it is the very essence of respiration to get rid of it and aqueous vapour, and to introduce into the blood a

new supply of oxygen, thus converting it into bright-coloured arterial blood.

The carbonic acid present in blood is there in two conditions. It partly exists in the state in which it is present in soda-water, and partly in combination with alkaline bases, notably soda. By certain chemical changes that occur, the whole of the carbonic anhydride is set free in the lungs, and it escapes along with watery vapour through the lung tissue into the respiratory passages. In exchange, the oxygen from the inspired air is absorbed by the blood, where it enters at least partly into combination with its colouring matter, and is conveyed thereby to all parts of the body.

The manner in which arterial blood performs its oxidation in the system has been beautifully illustrated by an experiment devised by Schützenberger. He caused bright red arterial blood to circulate through a long system of hollow tubes constructed of gold-beater's skin immersed in a mixture of yeast diffused in fresh serum (without globules) at a temperature of 35° C. (95° F.). As the blood traversed the tubes it gradually parted with its oxygen to the yeast through the walls of the tubes, and then passed out at the end black and venous.

This parting with oxygen through the walls of the gold-beater's skin tubes serves also to illustrate the manner in which the blood becomes oxygenated in the lung tissue. The blood in the pulmonary capillaries (which are wide and thin-walled, forming an extensive network of small meshes) is

separated from the air only by their own walls and the delicate lung membrane. Under these circumstances, it is easy to appreciate how the blood parts with its carbonic acid and becomes oxygenated. Gas which is mechanically held in solution has a tendency to diffuse into any atmosphere until it is present therein in a proportion corresponding to that remaining in solution. In this way the carbonic acid escapes from the blood. Again, gases separated from each other by a porous partition, diffuse into each other with a rapidity inversely proportional to the square roots of their densities. This law applies to the carbonic anhydride set free from the blood, and to the oxygen contained in the air on the other side of the lung membrane. Indeed, the exchange in question is promoted and not prevented by the intervention of the membranes of the lungs and the coats of the blood-vessels.

The composition of ten thousand parts of ordinary air, and the same quantity of expired air, respectively, is set forth in the following table * :—

10,000 *parts ordinary air.*		10,000 *parts expired air.*
Oxygen	2,100	1,500—1,600
Carbonic Acid	4	470
Nitrogen	7,900	7,900

The quantity of air that passes through the lungs of an individual in twenty-four hours varies with individual habits and bodily conditions. Dr. E. Smith gives from 804,780 cubic inches to 1,568,390 cubic inches; whereas Huxley, in his book already quoted,

* *Huxley's Elements of Physiology*, p. 85.

states that, taking no exercise, it is estimated at 350 to 400 cubic feet.

The water given off through the lungs in twenty-four hours has been estimated by Smith at an average of 311 grms., and the carbon (as carbonic anhydride) at from 7·144 to 11·7 ozs.

Oxidation in the human body is more active in youth than in advanced age; it is increased by cold and decreased by heat. Muscular exertion is the great incitive to active respiration, and by it the amount of carbonic anhydride expired may be doubled or even trebled.

Asphyxia results whenever the amount of carbonic anhydride present in tidal air reaches 10 per cent.; but uneasiness and headache are caused when even less than 1 per cent. of the atmospheric oxygen is replaced by other matters. This is important, as indicating the necessity of keeping the air we breathe fully oxygenated: the smallest diminution in the amount of oxygen present in the air suffices to cause very serious results.

Poisoning by carbonic anhydride is rather the result of interference with the ordinary functions of oxygen than that of any direct action.

According to Huxley, every man, in order to be supplied with sufficiently pure air, should have at least a breathing space of 800 cubic feet, and that space should be in direct and intimate contact with the open air, as otherwise the oxygen originally contained in the air of the apartment becomes seriously diminished in quantity.

Of the total oxygen consumed by the body, about 85 per cent. is given off therefrom in combination with carbon (carbonic anhydride), and the remaining 15 per cent. combines with hydrogen, and is given off as aqueous vapour, also, in respiration. Altogether, then, we find that 26·7 ozs., or more than 1½ lbs., of oxygen, are consumed daily by every adult. This weight of oxygen measures at the ordinary temperature and pressure, no less than 529,400 cubic centimetres, or about 117 gallons.

The figures above given, convey some idea of the process known as respiration, and lead to the perception that respiration is not adequately expressed by saying it maintains life. It is seen to mean something more than this; for if we take the quantity of oxygen absorbed daily by each individual, and multiply it by the number of the world's inhabitants, we shall obtain an astounding figure representing the sum total of oxygen daily removed from the atmosphere by human beings. Of course this quantity is increased by the amount also consumed by other animals, and it at once becomes evident that there must exist some natural process of restoration to the atmosphere of the oxygen thus removed, or otherwise in the course of ages the atmospheric proportion of this gas would get so small that life would become impossible.

Upon inquiry, it is found that plant life furnishes back to the atmosphere the oxygen which animal life takes away from it. It is a fact that the growth and development of vegetation depends upon its

elimination of oxygen from the very carbonic anhydride which animal life pours into the atmosphere. Priestley, who discovered oxygen, observed, for instance, that a pot of mint kept under a bell jar containing air which had been rendered impure by breathing, influenced the air in such a way as to make it fit to breathe over again. In short, the mint decomposed the carbonic acid, assimilating the carbon and restoring the oxygen to the air. What mint did in this simple experiment, is also performed by the green parts of all plants and vegetables, and particularly by the leaves. In this way, the composition of the atmosphere is kept practically constant and universal.

Of course it will be understood that, although the composition of the atmosphere is of a fairly constant nature, yet its actual percentage composition is not entirely uniform. For instance, in the midst of a dense assembly of men gathered together in a room, there would be found proportionately more carbonic acid and less oxygen in the air than in fresh country air; but there exists a law of nature which militates against such circumstances, and eventually overpowers all such localised effects. If we mix castor oil and water together, they will eventually separate, in spite of any amount of shaking, into two layers; but a similar behaviour is not observed with gases of different densities. Thus, if a heavy gas be brought into contact with a much lighter gas, the two will uniformly diffuse one into the other, and will not afterwards separate. This can be readily

appreciated if it be borne in mind that gases consist of particles of matter widely separated from each other; hence the particles of one gas can move into the spaces between those of another. This power or force of gaseous diffusion serves to prevent any evils which might arise from differences in the composition of the atmosphere owing to local circumstances. In the vicinity of limekilns, and in the neighbourhoods of human habitations, etc., much carbonic acid is generated into the surrounding air; but, instead of remaining in the locality, it is carried away by the power of diffusion, and uniformly distributed in atmospheric space. Aërial currents materially assist, of course, in carrying out this process.

If we consider that oxygen is truly what the older chemists termed it,—viz., vital air,—it is not surprising that a small animal should be able to live longer in a confined space filled with that gas than in an equal volume of air containing, as it does, a large proportion of nitrogen. Nevertheless, oxygen cannot be breathed with impunity for any length of time; and, indeed, when inhaled in the pure state, it exercises a severe poisonous effect. M. Paul Bert, who has devoted much time to the study of this subject, found that oxygen acts as a rapid poison when arterial blood contains 35 per cent., or nearly double the normal amount; the convulsions and death which result being due to a great exaggeration of the excito-motor power of the spinal cord. Compressed air exerts a similar influence. In dogs,

convulsions begin when the external pressure of oxygen is about 3½ atmospheres, or 17 atmospheres of air, and death occurs at 5 atmospheres of oxygen.

As found, however, in nature, the oxygen of the atmosphere is diluted to a large extent with nitrogen which is innocuous to health. It is by this dilution, the oxygen is rendered powerless to produce the evil results which follow when the pure gas is breathed, while its power to oxidise the matters presented to it in the blood is not in any way impaired.

Respiration is a sort of combustion, since the same kind of thing goes on in the two processes, and is attended with identical results; the only difference between combustion and respiration being one of outside conditions.

If the atmosphere consisted entirely of nitrogen, it would be just as impossible for a fire to occur as it would be for animals to exist; combustible matters and the oxidisable principles of blood equally requiring oxygen wherewith to combine. This process of oxidation or combustion is one which will have to be considered more fully hereafter, and the few words said about it here will pave the way for more important considerations.

Water and carbonic anhydride are not the only excretory products which result from oxidation within the living body. Other excretory products are passed through other channels; thus, urea, uric acid, and a number of allied compounds are carried away in the urine. Now, if the requisite amount of oxygen cannot

be obtained by the body, two evil consequences result; on the one hand, active oxidation is repressed and vitality is hence lowered; and on the other hand, waste substances accumulate in the blood instead of being carried off, regularly, so soon as produced. Such a state of things inevitably leads to disease; the tissues of the body do not obtain proper nutrition, and headache, palpitation, and hurried breathing are among the less serious results. Anæmia and consumption are among the more serious consequences of breathing air deficient in oxygen. In practice, it is found that at least 3,000 cubic feet of fresh air are required every hour for each person.

These facts are sufficient in themselves to indicate the great importance of having dwelling apartments properly ventilated; but they may be extended. It is known beyond all doubt that infection occurs through the air; that is to say, that the air may serve as the carrier of communicable diseases, and in proportion as the air is foul is also the danger of infection, for the very foulness serves as food for the germs which produce many diseases. The poison of typhus fever, whatever its nature, whether it be a living micro-organism or a chemical compound, is particulate, and in the dry state it can float in the air and be sucked into the living body with the air we breathe. When the poison thus imbibed finds a home in the intestine, typhus fever results. The same is in all probability true of the cholera poison, and of other infectants. By efficient ventilation, if such poisons be present, they are either

carried off from the immediate neighbourhood of our bodies, or the air containing them is diluted by the fresh air to such an extent, that the poisons are robbed of their power to produce disease.

It is with the view of preventing infection by the passage into the system of poisons floating unseen in the air that we resort to fumigations, and to the employment of respirators. By fumigation we seek to evaporate into the air chemical compounds known to be inhibitive to infectants, and by respirators we seek to strain off such infectants from the air we breathe, by means of a filtering medium, such as cotton wool impregnated, it may be, with a suitable disinfectant.

Air may be rendered impure in various ways. It is greatly polluted, as we have seen, by the breath of animals; it is polluted by the chemical products which are evolved from decaying and putrefying animal and vegetable matters, and also by the micro-organisms which originate these processes and are themselves multiplied thereby. It is also polluted by the smoke emitted from fires in dwellings, and by sewer gas which escapes from the ventilators ordinarily attached to sewers in towns, and which too often also escapes from the closets in our houses. There are further sources of pollution, but none which we need enumerate.

Decay and putrefaction are processes that should not be allowed to proceed in the vicinity of human dwellings, for not only are some of the immediate products poisonous, but they are believed to afford

the best nutriment to dangerous micro-organisms which prey also upon mankind. To prevent such processes from occurring in our midst we employ antiseptics and disinfectants.

The presence of smoke in the atmosphere is objectionable, because it is unnatural, and because it causes irritation in the air-passages of the lungs by introducing therein matters for the disposal of which nature has made no provision. As for sewer gas, it is not merely objectionable because it contains a number of gases poisonous in themselves; it is more especially to be dreaded inasmuch as it is liable to contain in suspension some of the micro organisms which are more particularly associated with specific communicable diseases. It is not too much to say that sewer gas should not be allowed to escape into the atmosphere until it has been subjected to some treatment which has been proved to be efficient for the destruction or removal of the organisms to which reference has been made. Water-closets, as they are too often constructed, serve only, through their connection with the sewers, as ventilators thereto, and are instrumental in admitting direct into the air of dwellings the very poisons that should be most dreaded. Where such arrangements cannot be readily remedied, we again rely upon the use of antiseptics or disinfectants, to supplement the action of the atmosphere. The manner in which the oxygen of the air acts as a purifying agent is one which will be further studied in the next chapter.

CHAPTER IV.

THE PROCESSES OF OXIDATION, SLOW COMBUSTION OR DECAY, AND PUTREFACTION; AND THEIR SANITARY BEARINGS.

IN a previous place it has been pointed out that the processes of respiration and combustion may be regarded as identical in kind, both being of the nature of oxidation. It will be necessary, here, to define this latter process somewhat more fully, and to follow out its natural history.

Oxidation, then, may be said to occur when one substance gives up oxygen to a second one, and the substance which receives the oxygen is said to undergo oxidation; in other words, it is oxidised.

Charcoal, in burning, combines with oxygen from the atmosphere; it is oxidised, and the product of the combustion is carbonic anhydride; thus:—

$$C + O_2 = CO_2.$$

If a jet of hydrogen gas be inflamed in an atmosphere of air or oxygen, oxidation also occurs, and water is produced, thus:—

$$H_2 + O = H_2O.$$

Again, if any hydrocarbon, such as benzene or tur-

pentine, be burnt in contact with sufficient air or oxygen, it undergoes oxidation, and yields water and carbonic acid gas as the ultimate products. For instance :—

$$C_6H_6 + 15\,O = 6CO_2 + 3H_2O,$$
$$\text{and } C_{10}H_{16} + 28\,O = 10CO_2 + 8H_2O.$$

In the same way, every organic substance which exists in nature or can be produced in the laboratory, is amenable to this process of combustion. It is only necessary to properly mix the substance with something capable of giving up oxygen at the temperature employed, or to subject the substance to a current of air or oxygen at a suitable temperature, to decompose it by the act of oxidation which always results in the production of carbonic acid and water.

Of course, substances like sugar, which contain some oxygen as a constituent, require relatively less oxygen to burn them than they otherwise would, since the self-contained oxygen serves, in a measure, to consummate the process; thus, sugar, in burning, becomes oxidised as here represented :—

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O.$$

It is seen, that if the sugar contained no oxygen itself, its carbon and hydrogen would require 18 atoms of extraneous oxygen for perfect combustion, instead of 12, as is the case.

Even with carbon compounds of the greatest complexity, as also with organised matters, the law of combustion holds good. For instance, albumin—

which contains, besides carbon and hydrogen, nitrogen, sulphur, and oxygen, is, during combustion, similarly decomposed. The carbon forms carbonic anhydride; the hydrogen forms water; the sulphur forms sulphurous anhydride (SO_2), and finally sulphuric anhydride; the nitrogen may be also oxidised, at least in part.

These, then, are the changes which organic compounds undergo when burnt or combusted in air or oxygen.

Respiration is combustion at a lower temperature; and in this process a number of carbon compounds, or waste products of the living body, are, in the blood or tissues, converted by oxidation into carbonic anhydride and water, which are finally given out in the breath. It must be observed, however, that this process does not take place with the living matter of the body, or, at least, it has not been proved to take place therewith.

The actual process of physiological combustion is one about which there is a deal of dispute. While Carl Voit* insists that oxidation in the body results as a consequence of tissue decomposition, and forms products by the combination of the inspired oxygen with the substances resulting from tissue change; other physiologists, such as Hoppe-Seyler,† maintain that the combustion of albuminous matters in the organism takes place in the living cells of the

* *Zeitschrift für Biologie*, viii., 297-388.

† *Pflüger's Archiv*, vii., 399-428.

tissues, and not in the lymph in which they are bathed, or in the blood, as held by some.

The bulk of evidence seems to be in favour of Voit's opinion, that the primary cause of tissue change is due either to ferments or some inherent cause which results in the production of certain proximate products of change, and that these being liberated into the juices of the body, combine with the oxygen there presented to them.

However this is, it may be accepted as generally true that, no organised substance, whether it forms part of a vegetable or an animal, is subject to oxidation, while it is vital. But, apart from the component parts of living tissues, there is no organised substance which can resist the process of oxidation as it is carried on in nature.

While life lasts, organised substances are protected from ordinary chemical influences of the kind under consideration, by reason of the concatenation of forces which govern their molecules; but when these combined forces are sufficiently disturbed, disease results, and when they are annihilated, then, death ensues, and the matter previously invincible by air and moisture now succumbs to their and other influences.

As respiration, although a rapid process of oxidation (seeing that 8·5 ozs. of carbon are daily oxidised in the body), is yet a slower one than that of ordinary combustion, so ordinary decay is very much slower than respiration. Nevertheless, it acts universally, and is omnipotent in its results.

In many places where mighty forests once stood, and where the soil had been impregnated for countless ages with humus and loaded with vegetable substances, there can now be found no trace of organic remains. A few years suffice to clear the soil once occupied by the primeval forests of America, of organic matters.

Under ordinary conditions, humus slowly decomposes, and the carbonic anhydride and other products are absorbed by the roots and other parts of plants, and converted into starch, gum, sugar, etc.; but if the plant life be cleared away, then the access of air to the soil is facilitated, and the molecules of organic matter are rapidly acted upon by the air and moisture, and leave the soil as carbonic anhydride and water.

The same process of slow oxidation occurs in cemeteries, where the dead bodies are gradually burned up, leaving only their mineral parts behind in the earth.

Naturally, there are conditions which specially favour this process, as well as others which militate against it. Eremacausis (as Liebig termed it) proceeds most favourably in the presence of water, and at a slightly elevated temperature. On the other hand, if the access of air be limited, the process goes on but slowly. Accordingly, it is found that, under such conditions, or where the air has been entirely precluded, organic matter may exist for a very long time. For instance, as all the world knows, dead bodies are preserved to a large extent

from decay by a method of embalming and wrapping, which keeps away the air and moisture so essential to slow oxidation. Indeed, the very existence of a mummy is, in its way, the best negative proof that could be submitted of the power of slow decay.

This marvellous process of oxidation is of infinite importance. By its action, the remains of animal and vegetable life are converted into the carbonic acid and water which are so necessary for plant life, and this, in its turn, gives back to animal life the oxygen which is essential to it. Thus the round of nature's operations is complete, and living matter is continually and for ever being reproduced from the same original substances.

The process of natural decay does not complete itself in one direct step, and this it is very important to understand. That is to say, compounds of vegetable and animal origin are not, by mere contact with the air, resolved by one direct step into carbonic anhydride and moisture. This undoubtedly occurs in combustion,—at least, for all practical purposes, this may be assumed,—but it is otherwise with eremacausis. This is gradual, and if not always, then at least generally, it occurs in several steps or degrees.

In some cases, the oxygen of the air so influences organic matter that, by its combination, two or three or more distinct substances result, and only one or all of these may be subject to a further degree of oxidation, and each may take a different time to fully undergo the process.

Again, a complex substance such as albumin (white of egg) may be split up, by certain influences (as by hydration), into several distinct substances before the oxygen of the air exercises any action whatever. This, however, afterwards begins, and then continues its work upon the derived compounds presented to it.

To make this clearer, it may be stated that when white of egg or blood albumin is boiled in the laboratory with certain reagents, maybe under a little pressure or otherwise, it is resolved into a number of distinct substances, but all of which undergo oxidation if they are now exposed to suitable influences, giving rise to quite a new series of substances; and these again can, by suitable means, be finally resolved into carbonic anhydride and water.*

No doubt, within the body (in respiration) and in nature, these conditions obtain, since within the body there are ferments, and in nature there are very low forms of life (micro-organisms), both of which are of sufficient influence to split up albumin into a number of proximate constituent principles before the air (or oxygen) has exerted any kind of influence. Indeed, it appears from the life-long labours of Pasteur and others that the process of slow oxidation really depends upon the development of organisms in the interior or upon the surface of the substances which are in course of decomposition, and

* Here, of course, for the sake of argument, we are only dealing with the carbon and hydrogen.

that in the absence of such organisms slow oxidation or combustion cannot occur. Just as the acetification of wines and beer depends upon vegetable growths (such as *mycoderma vini*) which possess the property of exciting oxidation in the solutions into which they may be introduced, so all other processes of slow combustion depend upon similar causes; and here we get a glimpse of the inutility of using agents like carbolic acid for the destruction of such vegetable ferments. For these ferments are ubiquitous, and have a great function; it is their natural province to cause slow oxidation in refuse matters, that is to say, in matters of animal and vegetable origin; and if we could by any possible means exterminate this branch of natural beings, we should interfere with the way which was originally created and intended to serve as one of the greatest sanitary measures for human welfare. We may, however, rest assured that this is not possible.

Putrefaction is a different process, but is allied to slow oxidation. The germs which initiate putrefaction cannot exist in the presence of oxygen, and as we shall see hereafter, the chemical act which they perform is not one of oxidation, but so far as has been ascertained, only a splitting up by hydration.

Since, in the first edition of this work I dwelt upon the processes of slow decay and putrefaction as the grandest natural measures afforded by Providence for the disposal of organic matters, the late Dr. Angus Smith took up the consideration of this subject in

an address delivered before the Sanitary Institute, in 1883.

Speaking of the impurities that pollute the Clyde, and of the population that has grown up along the banks of that river, he said, "If nature has contrived no method of destroying such seeds of death, populations such as this is would never have grown up. And what is the method? The method is, first, putrefaction; at least I know of none other, except the concluding portion of the work, viz., thorough oxidation. When, therefore, you see the Clyde seething with gases of putrefaction, and when you smell it to such an extent that a feeling of loathing is produced, you may remember this—that the work of destruction is going on with a wonderful rapidity, and that the enemies of life are being slaughtered there, millions upon millions, never to appear again in a similar form, though other generations of them may rise up." It will be seen by the reader that Dr. Angus Smith made the assumption that putrefaction must be the preliminary step to oxidation, but I doubt whether that assumption is well founded. Dry rot in wood is not preceded by putrefaction, and yet it is an active process of atmospheric oxidation carried on through the agency of micro-organisms. Again, the fermentation of alcohol into acetic acid is a process of oxidation carried on directly by the action of a cryptogam of the genus *Mycoderma*, and is typical of a number of combustions initiated by living organisms, which serve as media between atmospheric oxygen to the

fermentable matter. While, therefore, I admit that putrefaction often, and very largely, precedes the oxidation of organic matters, I still think that it does not necessarily precede it. There are, I believe, many other processes of fermentation carried on by the life agency of micro-organisms which equally suffice to prepare the subject-matters for thorough oxidation.

Notwithstanding what has gone before, putrefaction is a process which cannot lightly be allowed to proceed in and about human dwellings, because not only are many of the intermediate products poisonous in character and competent to produce disease in man, but the process is too often associated with particular micro-organisms greatly to be feared. The process is a sanitary one in its results, but only when it proceeds at a proper distance from the dwellings of men. Direct processes of oxidation may be allowed to proceed in and around our dwellings.

The chemistry of putrefaction will be studied more intimately later on, but it is worth while adding in this place, that sewage intended for use as manure is injuriously affected by putrefaction, for the process causes, and indeed is correlative with, a loss of substance, and constitutes the best preparation for a further loss of substance and value by the more direct and rapid process of ultimate oxidation which it induces.

Now, whatever oxygen, as air, is capable of doing in nature, in the shape of harmless oxidation, ozone and peroxide of hydrogen are much better qualified

to do. Whereas air is a mixture of gases containing only 21 per cent. oxygen, ozone is a dense form of this substance, being many times more active than even pure oxygen; moreover, when strong enough, it is, in all probability, fatal to those low forms of life which cause putrefaction, and others which are very intimately concerned in producing disease. In support of this, it may be mentioned that Tyndall found that when infusions of highly putrefactive matter were subjected to the action of ozone, they remained quite sterile, while the action of condensed air neither prevented their putrefaction, nor kept them free from germ life.

Peroxide of hydrogen also contains oxygen in a most powerful and active form: it no sooner comes into contact with oxidisable matters than it at once gives up its oxygen to them, in not only a pure but also a nascent state; and be it remarked that this is, universally, the most active state of gases. Moreover, by its liquid form (its wetness, so to speak) it is particularly qualified to come readily into absolute contact with substances. It has, also, been shown that peroxide of hydrogen is fatal to many kinds of germ life, including those known to produce certain specific diseases. Putrefaction cannot occur in animal or vegetable substances protected by it.

The probable influences of ozone and peroxide of hydrogen, so far as they concern sanitation, will be more fully discussed later on; here it is sufficient to point out that, as compared with the atmosphere, and weight for weight, they act far more rapidly and

powerfully as oxidants; and this very fact has a great deal to do with putrefaction and similar processes, as may at once be appreciated if we consider that, although some germs cannot live without oxygen, yet when it is presented to them in the form either of ozone or peroxide of hydrogen, they are either killed, or else prevented from carrying out their normal functions in compounds of an animal or vegetable origin, while septic organisms certainly cannot exist in the presence of peroxide of hydrogen.

Not only so, but ozone and peroxide of hydrogen exhibit another and significant feature. To illustrate this. It has been already stated that there are degrees of oxidation. If turpentine be heated in contact with water and a stream of air, it suffers a change of a definite kind, but it is one which is gradual, and, amongst other products, peroxide of hydrogen is produced; but if turpentine be heated with nitric acid (also an oxidant, only far more violent than air) it suffers a radical and quick change; the whole of the oil disappears, and if continued sufficiently long, the process gives only carbonic acid and water as ultimate products. Now let us pass from turpentine to albumin. If this substance be exposed to the air, it softens; and by the united action of water and air (under the primary influence of ferments), undergoes a complex process termed putrefaction, which is attended with the production of a number of substances, some of which are known, and some of which have not been determined. In process of time, however, the putrefaction passes

away, and oxidation proceeds further, until the whole of the mass is oxidised into ultimate products. But if the albumin, instead of being exposed merely to the air, be boiled with dilute nitric acid, the end result is reached in a period of time which is infinitely more brief than that occupied by the more natural process of destruction.

Ozone and peroxide of hydrogen being similarly stronger agents of oxidation than the air, although not destructive and caustic like nitric acid, also have the power of avoiding the putrefactive process to which allusion has been made; or if that process has already occurred, then, of burning up or oxidising the products which are of a noxious character. If now, it be reflected how much matter of animal and vegetable origin is given back to nature—and particularly among human populations—for disposal in a way which shall restore their elementary principles to a useful purpose without the attendance of disease, we obtain an insight into the importance of the process of oxidation, and can see why, at particular times and in special places, peroxide of hydrogen and ozone, two substances generated naturally, should exercise notable and beneficial influences.

Putrefaction is a process of such vast importance, that it is necessary in this place to bestow upon it some little further special study.

In the first place, it may be remarked that the number of putrescible substances is not great, but they are universally distributed, being derived, as they are, from every organised being. Indeed, putrescence is

a property almost or quite exclusive to the albuminous substances of which the flesh of animals is mainly composed, and which also enter into the composition of vegetable principles. It is these very substances which succumb most readily to decomposing influences. To understand this subject clearly, it must be borne in mind that no kind of substance has an inherent tendency to change except real living, germinal matter. No distinctly chemical substance has any tendency to change, although we often speak of certain substances being unstable, or having such a tendency. What is really intended is to express the fact that some matters are more sensitive to extraneous influences than others.

Albumin is a chemical substance which, like all other chemical substances, exists in virtue of certain forces of combination between its constituent atoms; and by protecting it from outside attacks, it may be kept unchanged for an indefinite length of time, or eternally. But when it is exposed to ordinary air and the presence of water, it is open to the attacks of certain low forms of life which abound therein, and to which it becomes pabulum, and under their initial influence putrefaction sets in, and oxidation into ultimate products ends the history.

Liebig knew very well that if blood be protected from the air, it does not pass into putrefaction; but he was wrong in supposing that it was the air itself which caused the blood to putrefy in course of time. It is not the air, but something which is in the air, viz., germs, or minute forms of life (micro-

organisms), which are invisible to the naked eye under ordinary conditions, but which are known to form part of the vibrating motes to which a ray of light passing through a darkened chamber owes its visibility (*Tyndall*). That this is so, has been well confirmed in some later experiments made by Lister, in which he demonstrated the fact that newly collected blood neither coagulates nor putrifies if care be taken, while collecting it, to exclude the presence of these micro-organisms contained in ordinary air. This may be done in several ways well known to scientific men. Air can be freed from its contained living matter either by heating it to a temperature sufficiently high to destroy it, or by filtering it through plugs of cotton wool, the meshes of which retain the micro-organisms, etc.

Recent researches have shown that germ life is ubiquitous, and embraces an immense variety of species, so that the atmosphere is ordinarily loaded with a large number of forms. Accepting, therefore, the views of Pasteur, who has devoted his life to such studies, and taking blood serum to illustrate a putrescible substance, the history of putrefaction may be thus described:—One or more micro-organisms (vibriones) fall into the fluid, and by feeding in the medium which is suitable to their development, they propagate their species. Since they live upon the albumin which is in the serum, they thereby decompose it, splitting it up into a variety of products. Simultaneously, a film of other micro organisms (bacteria, mucors, and mucidines) forms on the sur-

face, from the introduction of other germs. Now, the life act of the vibrione is the impulse requisite for the decomposition of the albumin,—for the initiation of putrefaction,—and it may be fairly compared with the power of the liver to prepare bile from the albumin presented to it in the blood. It is even conceivable, if not probable, that the vital function of the vibrione is one of hydration (fixation of water), that is, one which results in the same products, or some of them, as are obtained when albumin is boiled in the laboratory, say, with baryta water or dilute sulphuric acid.

Oxygen is fatal to the vibriones which are here mentioned, but being beneath the surface of the fluid, they are practically protected from its effects. On the other hand, the bacteria which grow on the surface of the serum require oxygen for their very existence, so that they excite and accelerate the slow combustion of the first products generated by the initial impulse communicated by the vibriones to the albumin. As a final result of these changes, the vibriones and bacteria also die, pass into putrefactive change, and become oxidised with the rest of the matter.

Now, the particular forms of life which thus induce putrefaction, and those other living germs by whose agency slow combustion is eventually carried out, are, apparently, quite harmless in themselves when present in their ordinary numbers, since, being ubiquitous and freely inspired with the air and contained in the water we drink, no evil result

is produced. Nevertheless, vibriones can convert serum of blood, which is perfectly harmless when fresh, into a poisonous mass. It has been shown by Panum and Burdon-Sanderson that putrilage, even when absolutely freed from every kind of germ life, yet contains a particulate matter which, if introduced into the blood system of animals, produces septicæmia.

The reader, to thoroughly appreciate the meaning of these facts, which have been ascertained with extreme care and with great precision, must keep his mind free, for the time, from all other considerations. Here a clear issue is presented: germ-life, harmless in itself under ordinary conditions, produces in the process of putrefaction a blood or septic poison. Whether this is the direct consequence of a vital act,—the septic poison thus resulting as a chemical product of the pabulum consumed,—or whether the organisms secrete a ferment which does all the chemical work, is not decided. Such a chemical ferment or secretion may possibly have for its function the preparation of the dead matter as pabulum for the organisms, just as gastric juice prepares food for assimilation in the human body.*

Hereafter, more particular attention will be paid to the subjects of germs and infectious diseases.

In concluding this chapter it is only fair to indicate the great extent to which we are indebted to Pasteur

* See Dr. Drysdale's Essay on the Germ Theories of Infectious Diseases, pp. 5 and 6.

for his masterly researches on putrefaction and fermentation. It is no exaggeration to say that, we owe the larger part of our knowledge of these processes to his investigations. It was in 1863, that he defined * putrefaction as a fermentative process induced and sustained by animal ferments of the genus *vibrio*. This definition subsequently received confirmation from Traube and Gscheidlen † (among many others) in 1874.

More recently, M. Pasteur has found it necessary to divide living organisms into two large classes, which he designates *ærobies* and *anærobies*. The first class require for their growth the presence of oxygen; while the second group can dispense with it entirely. Thus, as has already been shown, septic vibriones are killed by free oxygen; and, indeed, putrefaction cannot be induced in a substance until certain other organisms (mucors) have first of all used up any oxygen which may be present. It has been my privilege to confirm the general history of putrefaction and oxidation of which I have given an account, by some special experiments recently contributed to the Chemical Society.‡

Finally, it must be remembered that slow oxidation or eremacausis is a process which must be deemed to occur in nature apart from putrefaction, at least in most cases. The two processes are in essence quite

* *Compt. Rend.*, lvi., 1189; *Jahresb. f. Chem.*, 1863, 579.

† *Dingl. Polyt. J.*, ccxxii., 352.

‡ Contributions to the History of Putrefaction, Part I., *Journ Chem. Soc.*, January 1880.

distinct, and depend upon entirely different micro-organisms. At times, undoubtedly, putrefaction either precedes or progresses simultaneously with slow combustion. Sanitary science cannot materially interfere with Nature's grand law of slow combustion; but it can, and does, aim at preventing putrefaction, together with all the evils that are apt to follow its course, when that occurs in or near human habitations; but where it occurs far away from populated places, putrefaction itself must also be considered as a sanitary process of the very first order.

CHAPTER V.

WATER AND WATER SUPPLY.

WATER is not found in nature in a perfectly pure condition. Its solvent powers are so great that it dissolves from the atmosphere and from the earth a variety of substances which, from a strictly chemical point of view, must be viewed as impurities. That is to say, they have nothing to do with the composition of water as water, and are indeed foreign to it. Nevertheless, they are not necessarily objectionable from a sanitary point of view.

Rain water collected after some continued fall, is as nearly pure as it can be found in nature, but even then it contains about 2½ volumes of air dissolved in each 100 volumes by measure. Such rain water may be regarded as practically pure, and while upon this subject it may be remarked that it is a great pity that its collection for domestic employment is not more extensively carried out. The earlier fall of rain water collected after dry weather is contaminated with traces of nitrates and nitrites, salts of ammonia, and some organic impurities, but none of these impurities are of very serious moment, and efficient filtration would make such rain water quite fit for

many purposes, and the later portions would be quite safe, even for drinking use.

After water has once come into contact with the soil, it becomes a solution of a number of saline substances, and it may also take up from animal and vegetable sources a considerably larger proportion of organic matter. The nature of the salts thus entering into solution depends, of course, upon the character of the soil, but among the most usual impurities are chloride of sodium (common salt), carbonate of calcium (chalk), sulphate of calcium (gypsum), and sulphate and carbonate of magnesium. The increase in the quantity of nitrates and salts of ammonia found present in town waters is owing to contamination with decaying organic matters or with sewage which is undergoing oxidation by the air.

Most spring waters are charged with a considerable quantity of carbonic anhydride, which increases the capacity of the water to dissolve calcic carbonate. This explains why the waters derived from calcareous springs around London contain from 18 to 20 grains of chalk per gallon, but this quantity is diminished upon exposure to the air, as during such exposure, carbonic anhydride escapes from the water, and this causes the precipitation of part (amounting on the average to one-third) of the chalk. The so-called "hardness" of water is due to the presence of these dissolved substances collectively, and in the main to the mineral constituents. The mineral (inorganic) constituents, however, are otherwise unobjectionable in drinking-water; it is only the organic matter that

may render the water unfit for potable purposes. A general support is given to this statement by the well-known fact that so-called "mineral" waters are taken on account of their reputed medicinal value, which is due to the salts that are present in large quantities.

Still more largely contaminated with dissolved salts is sea water; this has a specific gravity of about 1025 to 1027, and contains very large quantities of common salt and chloride of magnesium. The water of the British Channel contains 28·05 parts of common salt, 3·66 parts of magnesium chloride, and 4·7 parts of other mineral substances in each 1000 parts of the solution.

River water is of the greatest importance from our point of view, since it is from rivers that most of our large populations derive water for drinking purposes. It often contains less saline matter than spring water, but is much more liable to be heavily contaminated with organic matter derived from the extensive tracts of country which are drained into it. This organic matter is partly suspended and partly dissolved. The coarser suspended parts (weeds, fish spawn, leaves, twigs, grass, and fine mud) can be readily removed by subsidence and filtration, but ordinary filtration does not materially affect or remove dissolved organic matters, and is not supposed to remove micro-organisms, although they are in suspension.

The further elucidation of this subject may be as well carried out by taking up the study of Thames

water, from which the London water supply is mainly taken.

The Thames is contaminated not only by persons who bathe in the stream and by the dogs that are washed in it; it also derives a great deal of organic matter from the land on its banks, and particularly after the application of night-soil and other manures thereto, followed by a downfall of rain. Further, and chiefly, it is polluted by the untreated sewage of towns which in the upper Thames basin alone have a collective population of 72,628 persons, and the treated sewage of towns with a total population of 196,593 persons. The treatment of sewage, as here referred to, means the removal therefrom of the whole of the suspended matters, but it does not seriously affect the composition of the liquid part (effluent) which is then discharged into the river.

At first sight, it would appear reasonable to condemn such a river as the Thames as the chief source of the water supply for London upon the mere evidence that sewage is conveyed into it, but the analysis of the water actually delivered in 1883 does not lend confirmation to this view; for, it is seen that the total solid matters contained in the water amounted to only 28 parts in 100,000, and of this quantity only 0·174 consisted of organic carbon, and 0·031 of organic nitrogen. That is to say, the organic substances present in 100,000 parts of the water furnished, upon analysis, the recited quantities of carbon and nitrogen.

The dissolved organic matter in potable water

never amounts to more than from $\frac{1}{5000}$ to $\frac{1}{1000}$ of a per cent., and it cannot be pretended for a moment that anything more than a minute fraction of this small quantity is of a living nature; the bulk of it is certainly innocuous.

The following table is taken from a paper by Prof. W. Odling *:—

Means of Eighteen Monthly Analyses, 1883—1884.

Source.	Proprietary.	Organic Carbon.		Organic Matter.
		Parts per 100,000	Grains per gallon	Grains per gallon estimated.
Chalk Springs . .	Kent Company .	·047	·033	0·083
River Lea and Springs	New River Company	·089	·062	0·156
Mixed . . .	Birmingham Corporation . .	·132	·093	0·231
River Lea . . .	East London Company	·139	·098	0·245
Loch Katrine . .	Glasgow Corporation	·147	·103	0·257
River Thames . .	The Five Companies	·164	·115	0·286

A consideration of these analytical figures shows that the organic impurities present in Thames water amount to barely twice the quantity contained in unpolluted waters, and the conviction is forced upon us that after all some great system of purification must be at work in the river Thames, and indeed in all running streams.

One of the opinions of the River Commissioners, expressed in their Sixth Report, was as follows: "Rivers which have received sewage, even if that sewage has been purified before its discharge, are

* *Journ. Soc. Arts*, vol. xxxii., p. 984.

not safe sources of potable water." It is our province in this chapter to seek to ascertain wherein lies the danger, and whether that opinion is to be accepted as representing the truth. There can be no doubt of the fact that the Thames is heavily contaminated throughout a great part of its course with organic matter (say sewage). How is it then that the water taken from the river, and delivered for consumption in the Metropolis, is so comparatively pure, anyhow as regards the actual quantity of foreign substances present therein? No doubt, a very large proportion of the solid parts of excremental matter carried into the river becomes deposited upon the bed of the stream and upon its banks, while the soluble impurities are diffused in the mass of the water, which is diluted from time to time by heavy falls of rain; for it must be remembered that the Thames drains an enormous tract of country, and although it receives impurities throughout its course in consequence, it also receives continually increasing quantities of comparatively unpolluted water derived from the rainfall. This water is naturally aerated; that is to say, it contains dissolved oxygen: and then again the water in the river is exposed over its whole surface to the atmosphere, and being a running stream, new surfaces are being continually brought into direct contact with the oxygen of the atmosphere. Under these circumstances oxidation rapidly proceeds by the operation of those laws which have been described in some detail in a previous chapter, and it is at least comparable with the rapidity with which nitrification

takes place in soils which are laden with organic refuse. Further, it must be borne in mind that the vegetable growths which line the banks and bed of the river, as also the fish which inhabit the water, and the birds and winged insects which resort to the water for food, all act as scavengers to the stream, and assist in its purification.

That oxidation does proceed in the manner referred to, is best proved by the analysis of Thames water as delivered to the consumers, although there is no good reason for disputing it. Dr. Meymott Tidy has endeavoured to obtain direct evidence upon this point,* and while he has, in my opinion, claimed too much for the process (that is to say, he has sought upon several occasions, to put upon the process of oxidation an amount of work it cannot perform in a given time), yet he has materially assisted the education of the public upon this important subject. In his experiments he employed "a series of twenty troughs each ten feet long, and constructed of two pieces of wood joined together at a right angle. Each trough was so placed that it had a fall of one inch, the water from one trough being discharged into a second placed under, but a few inches distant from it." Subsequently he was compelled to line the trough with glass, and to take many precautions to keep out "blacks" and other impurities. I will now quote the results of one of his experiments. Water

* *Journ. Chem. Soc. Trans.* 1880, p. 307.

was allowed to flow from a cistern placed above the uppermost trough, over the entire length of troughs, and then pumped up again to the highest trough, and so forth. In this way six gallons of New River water, containing 5·55 per cent. of added sewage, travelled one mile in 8½ hours, the temperature of the air ranging from 57° to 64° F., and that of the water from 55° to 61° F.

Analysis:—

	Oxygen required.	Organic Carbon.	Organic Nitrogen.	Chlorine grains.
		Parts per 100,000.		
Before experiment	0·391 grains.	0·436	0·156	1·40
After experiment	0·181 „	0·274	0·100	1·44
Results	—·210 „	—·162	—·056	+0·04

This and the other experiments may be accepted as giving evidence of the oxidation which proceeds in running water freely exposed to the air, but at the same time it cannot be accepted as substantiating the statement said to have been made by Dr. Tidy, to the effect that the polluting matter from sewage entering the river Colne was "entirely destroyed after proceeding half a mile." I think this statement represents a great exaggeration of the power of atmospheric oxidation, and I say this advisedly, having paid much attention to the study of various processes of air-oxidation.

In a paper* which was communicated to the Chemical Society in 1880, I brought forward some

* *Journ. Chem. Soc. Trans.* 1880, p. 15.

experimental evidence as to the manner in which organic matter present in water is gradually destroyed by the agency of micro-organisms, and I endeavoured to show by experimental figures that the primary chemical act of putrefaction thus induced is one of hydration, the secondary change being one of oxidation carried on by the agency of a distinct class of micro-organisms. Later on, when the subject of water supply was prominently before chemists, I described in another paper* some further observations of the same class, and also an experiment, the result of which gave support to Dr. Tidy's experimental results above recited.

An aqueous extract of meat was allowed to pass into putrefactive decay, and periodically, its oxygen-absorbing capacity was experimentally determined. Expressing the results in grammes and gallons, it was found that, whereas, at the start (when fresh), a gallon of the extract used up 6·656 grms. of oxygen (from the oxidising agent employed), after 39 days a gallon only used 5·79 grms., and after 155 days only 3·243 grms. The diminution in oxygen thus consumed indicates the amount of oxidation which had proceeded in the meantime; the oxygen being absorbed from the air. A current of air was now blown through a quantity of the putrid extract during twenty-four hours, after which it was found that the oxygen-absorbing capacity had fallen per gallon from 3·243 grms. to 2·234 grms. oxygen. The

Chem. News, vol. xli., p. 254.

difference represents oxygen used up from the current of air during the twenty-four hours.

That sewage, therefore, will under ordinary circumstances be destroyed in a river cannot be disputed. It is only a question of time, temperature, and length of the river. It is of the greatest importance to bear in mind, however, the fact that this destruction depends upon the life of certain organisms; indeed if they be wanting, or if they be killed by chemical agents, the destruction of the organic matter will be postponed, the chief condition requisite for purification being wanting. Although the oxidation of organic matter dissolved in water is carried out directly through the action of micro-organisms, oxygen itself is necessary as a correlative part of the phenomenon, and in connection with this subject I may quote some figures employed upon a recent occasion for illustrating the same truth, by Professor W. Odling.* At a summer temperature of 70° F. water contains 1·8 cubic inches of dissolved oxygen per gallon, and 2·2 cubic inches at a winter temperature of 45° F. The smaller quantity thus held in solution amounts to 2·58 tons of oxygen per 10,000,000 cubic feet of water, and the larger quantity is 3·16 tons. According to a calculation that has been made, sixty-four million cubic feet of water pass through Teddington lock in each twenty-four hours during dry weather,

* In a lecture delivered before the Royal Institution on May 16th, 1884. See abstract in *Pharm. Journ.*, May 24th, 1884.

and this would contain 17¼ tons of dissolved oxygen; by the time this body of water reaches Somerset House it is found to have lost from 12 to 13 tons of oxygen, and this loss is supposed to represent the quantity used up in the meantime in the oxidation of sewage matter.

In connection with the subject of the self-purification of water, the observations recently made by Dr. Pehl * upon the water of the Neva are of some interest. This water is stated by him to be poor in bacteria, since it contains only about 300 germs in each cubic centimetre. After heavy rains the number rises to 4,500, and during the thawing of the river to 6,500. On the other hand, the water in the canals of St. Petersburg, which are fed with the water from the Neva, is infested with bacteria, their number reaching 110,000 in a cubic centimetre even in good weather. At the same time the chemical composition of this water is nearly identical with that of the Neva. He explains the anomaly upon the assumption that the purification of water is to be attributed in some measure to its rapid motion, and in order to test the matter he brought water into rapid motion (in contact with air?) by means of a centrifugal machine during one hour, and found that the number of developing germs was reduced by 90 per cent.

Personally, I do not attach any very great value to

* Abstract of a paper in the *Journal of the Russian Chemical Society*, given in *Sanitary Record*, vol. v., p. 597.

such bacterioscopic measurements, although it must be understood that by this remark I do not seek to throw any discredit upon the observations of Dr. Pehl. I rather wish to emphasise the fact that such bacterioscopic measurements may be exact or inexact: there is great doubt about the matter on account of the minuteness of the objects. It is different, however, with the larger animals met with in fresh water, and this is a subject which has recently been studied by Sorby,* who has endeavoured to ascertain the number contained per gallon, of the various small animals which are large enough not to pass through a sieve the meshes of which are about $\frac{1}{200}$ part of an inch in diameter. The chief animals met with in fresh water are various entomostraca, rotifera, and the worm-like larvæ of insects, and Sorby has found that the number per gallon and percentage relationships of these, mark in a clear manner changed conditions in the water, "the discharge of a certain amount of sewage being indicated by an increase in the total number per gallon, or by an alteration in the relative numbers of the different kinds, or of both."

Entomostraca will eat dead animal matter, and Sorby has kept them alive for many months by feeding them on human excrement, while they soon died without it; although this fact must not be taken to indicate that they are entirely dependent upon it. Now though, as in the case of larger animals, a considerable part of their excrements must

* *Journ. Soc. Arts*, vol. xxxii., p. 929.

consist of putrescible organic matter, there can be no doubt that the amount of sewage matter they consume is very great, and as a net result the dissolved organic matter present in water must be considerably diminished by their multiplication and their life processes.

Minute plants (diatoms, desmids, and confervoid algæ) may also play an important part in the purification of water, since when exposed to the light they decompose carbonic anhydride and liberate oxygen which is required by animal life.

Dr. Jabez Hogg,* however, thinks that Sorby's examination of "the coarser and more palpable contaminations of water will, under any circumstances, be of little moment. It is the minuter forms of organic life with which medical men are much concerned, and which are known to be of vital importance as matters of hygiene," and he has called particular attention to the fact that the presence of large numbers of the various entomostraca, etc., is in itself the best evidence of the impurity of the water in which they abound, and that they have often been known to produce serious outbreaks of illness (diarrhœa and dysentery). Without disputing the truth of Dr. Hogg's statements, I think they do not diminish the force of Sorby's contention; for it cannot be denied that animal life, no matter in what medium it be carried on, is sustained at the expense more or less of the pabulum upon which

* *Journ. Soc. Arts*, vol. xxxii., p. 939.

it subsists, and although it may be dangerous to drink water at a stage wherein it abounds in animal life of a comparatively high pronounced type, the water is made less dangerous by the fact that it is thus rid of some of its organic impurities, and therefore affords less encouragement for the development therein of those still more subtle and dangerous micro-organisms to which Dr. Hogg exclusively confines his attention.

Mention has been made in an earlier place of the argument which is advanced by many to the effect that when once a water-course has been contaminated with sewage matter, the water is rendered unfit for drinking purposes for all time. Not that some of those persons who advance this argument deny the purifying influences which have been described as being at work in running streams, but because disease germs may be introduced with the sewage matter, and it is contended that such germs are not destroyed along with the dissolved organic matter. In taking part in a recent discussion of this matter, Prof. E. Frankland said, "From a strictly physiological point of view, the admission of sewage into the water supply of a town did not necessarily affect the health of the inhabitants drinking the polluted water; but if you have fever epidemics occurring upon the banks of such a river, if you have abnormal or infected sewage discharged into it, then you run a very great risk: you run a risk probably proportionate to the number of infected persons contributing to the sewage."

In the same discussion, Dr. Jabez Hogg on the same side referred to "the remarkable instance which occurred at Caterham Waterworks, where by the merest accident of one workman suffering from typhoid fever, who went down into the well and worked there a few hours, and defiled the well, thus contaminating hundreds of millions of gallons of water which were pumped out and distributed to the townspeople round about, four hundred cases of typhoid followed the next week, and seventy or eighty deaths occurred in consequence."

Thus, it is urged that neither dilution nor oxidation of bad water will make it good, and experiments are not wanting to give support to the idea that disease germs are all but indestructible: they are said to require hours of boiling to kill them, and are reported to be unaffected by such chemical reagents as cyanogen and sulphurous anhydride, and other equally poisonous substances. Now as regards the experiments with poisonous gases, which were conducted for Prof. E. Frankland, I could state several excellent reasons why they should not be regarded as furnishing acceptable evidence of the contention he has based upon them, but this is not the place for such a criticism, and I will therefore only invite my readers to place the matter on one side in their minds, and to confine attention to the more general statement concerning the persistent vitality of disease germs or micro-organisms.

These disease germs are of the same order in nature as the micro-organisms which breed common putre-

faction; they have the same short life history. The history of their life-actions corresponds in all respects with the history of the vital actions of the vibriones that induce putrefaction, and the bacteria that cause oxidation of organic matter in water,—they die themselves and pass into putrefactive decay; and just as micro-organisms of putrefaction can be readily killed by a thousand chemical reagents, so, in all probability, are the micro-organisms of disease subject to the same or similar influences. Their action can be arrested, diverted, or totally annihilated by the means which are commonly employed in medical practice for the treatment and cure of infectious diseases. The idea that micro-organisms have such a persistent vitality as is often represented arises, in my opinion, from a confusion of facts. The truth is that these low forms of life multiply very rapidly so long as pabulum be afforded and the other conditions necessary to their existence be present; and too often, I believe, in course of observations, successive generations have been confused with the original organisms from which they proceeded. The yeast cells which give rise to the production of alcohol in a solution of sugar, are themselves killed by this very product when its proportion present in the solution rises to a certain definite extent, and so also other classes of ferments are destroyed by the products of their own life actions, not to speak of outside influences which may be brought to bear upon them at will. It is not to be denied that, as in the Caterham case above mentioned, the introduction of disease germs into a

water used for drinking purposes, may lead to an epidemic, but it must be remembered that in this case the water was immediately delivered for consumption, and certainly it was not exposed to those conditions which must be accepted as constituting purifying influences, extending even to the destruction or removal of disease germs. Had the contamination, for instance, occurred at Oxford, then, I believe, the Thames water, as delivered at London, would not have caused further cases of the disease. And the proof is near to hand, if further proof be wanted, and it is furnished by statistics, if statistics prove anything at all. Mr. Baldwin Latham has compiled a paper, in which he has compared the zymotic death-rate of those districts which derive their water supply from the river Thames with those districts which obtain theirs from the chalk, and taking diarrhœa as a disease peculiarly attributable to bad water, it is seen that the death-rate in the district supplied by Thames water is actually slightly lower than that supplied by the Kent Water Company. Such a fact as this is simply irresistible. The fact is that atmospheric oxygen not only resists putrefaction, but it is absolutely fatal to a large class of micro-organisms, and it is idle to deny to atmospheric oxygen in nature the properties it has been proved to possess in the laboratory by men like Pasteur, who is an apostle of the new teachings of sanitary science. Further, the difference in composition of Thames water and the deep chalk waters of Kent is so slight, and the proportion of organic

matter dissolved in Thames water is so small, that even if it could be shown that the liability of different waters to contain disease germs in active vitality was in proportion to the relative amounts of dissolved organic matter, the relative superiority of the one water over the other for potable purposes is practically insignificant.

There can be no doubt that the provisions afforded by nature for the purification of the atmosphere are equally effective for the purification of water in a running stream. The air of towns is largely contaminated with organic matter, and is directly polluted, in the most real sense of that expression, with the germs that initiate disease. These germs are given off from the bodies of persons suffering from infectious disease, both externally (from the skin) and internally (with the breath and excreta), and must pass, in great measure, directly into the atmosphere. What is the consequence? To some extent, of course, they infect other persons, but by far the larger number must die either by a process of starvation, or by the action of fresh currents of air. Air which has been contaminated with sewage, or even with the most virulent germs of disease, thus again becomes fit to be breathed, and it is idle to deny that the same process of purification takes place in running water freely exposed to the air. If we are to condemn to all time water which has once been contaminated with sewage, we must equally condemn our air-supply, and with the same zeal look out for a new one.

As a summary of what has preceded, and in order to resume the thread of our considerations, it may be stated that while Thames water, as now delivered to London for drinking purposes, is sound in quality, it is desirable that all possible means should be taken to exclude sewage contamination throughout the course of the river, and in particular at Oxford and thence to the pumping-stations near Teddington. This is desirable, because the germs which cause cholera and typhoid fever (not to mention any other diseases) are contained in the stools of patients suffering from these diseases, and if they be swallowed while living, they may communicate the diseases to further persons: it is also desirable because all the organic matter that is introduced into the river has to be oxidised or otherwise destroyed, or removed; and the less therefore that is introduced, the smaller is the tax made upon the purifying agencies that are at work. Moreover, it may be conceded that an impure water, loaded with fœcal matter, affords much better pabulum for the maintenance and reproduction of disease germs than a pure water practically devoid of organic matter suspended and dissolved. In my opinion, therefore, no untreated sewage should be allowed to enter the Thames from its source to its mouth. Wherever there is sewage to be disposed, it should be so treated that the solid parts are removed or separated from the liquid parts. The solid parts should never be allowed to enter the river, and if the liquid parts can be passed over land before entering the river, so much the better; but the impurities

conveyed by the liquid parts are insignificant as compared to the solid parts, and are destroyed in course of time by oxidation.

In connection with this part of the subject I am entirely at one with Mr. Cresswell* in thinking that the public at large owe a debt of gratitude to the companies who have risked much capital and expended much labour and time in seeking to remove from sewage its solid parts by precipitation or otherwise, and thus keeping it out of the river Thames. A similar debt of gratitude is due to all reformers in sanitary science, and to all who increase the means of lessening human suffering, no matter in what direction.

As regards the purification of water by artificial means, very few words will suffice. We have seen with what good effects the oxidation of organic impurities is carried out naturally; it is, therefore, justifiable to believe that the purification could be carried still further, when desirable, by an artificial process, in which the water before or after filtration should be exposed to a current of air. This current of air might be pumped, under pressure, into the water contained in a suitable vessel, or led into the water contained in the reservoirs. For this latter purpose all that is required is a series of perforated pipes, lying upon the bed of the reservoirs, and conveying air direct from the pump. I have a very strong opinion that the London and other water companies might profitably make use of this suggestion.

* *Soc. of Arts Journ.*, vol. xxxii., p. 450.

In a recent paper,* Mr. W. Anderson, M.I.C.E., has described the purification of water by means of iron on a large scale. The process consists in bringing the water into intimate contact with a mixture of spongy iron and gravel, and has been applied for some extended period to the water of the river Nethe at Antwerp. Acting upon a suggestion made by Sir Frederick Abel, to the effect that if iron exerted a purifying influence on water, it would obviously exert it to the greatest extent in a given time, if the surfaces of the iron and water coming into contact were constantly renewed, Mr. Anderson made use of a revolving cylinder, fitted with inlet and outlet pipes, and with shelves or ledges for scooping up the iron, etc. In actual use he managed to get 166 gallons of water passed through the "revolver" per minute: this gives a contact of about 3½ minutes, and is said to be amply sufficient. The charge of iron is about 500 lbs., and the water takes up (dissolves) and mechanically carries away about 0·176 grain per gallon. Mr. Anderson adds: "By making suitable arrangements, and choosing a favourable time with respect to the demands of the town, we were able to obtain samples of water that have been purified by the 'revolver' only, and after proper exposure to the air, followed by filtration through one of the large sand filters, the result obtained has been that the colour was very little different from distilled water, the free ammonia was reduced from

* *Society of Arts Journal*, vol. xxxii., p. 963.

0·032 grains per gallon to 0·001, and the albuminoid ammonia from 0·013 grains to 0·0045."

The iron used in this process may be supposed to act in several ways; firstly, as a mechanical agency for bringing the particles of water into intimate contact with particles of air contained in the vessel; secondly, as a filtering or screening agent, aggregating to itself the suspended particles of organic matter previously contained in the water; and thirdly, by passing to a small extent into solution, in which case it may be supposed to act as a chemical carrier of oxygen to the organic matter dissolved in the water; for the iron in solution would presumably be first oxidised to the ferric state, and alternately reduced to the ferrous state. The purification of the water, however, is not entirely due to the action of the iron: it is partly due to the subsequent exposure to the air, and also to the filtration through sand. Whatever action iron may have, it can only assist in the process of purification, which is really effected by the agency of oxygen.

These few remarks lead us to the subject of domestic filters, which primarily act as strainers, removing from the water the larger suspended particles; but it is to be doubted whether the best of them do much more than this. The agents which are used in them (such as prepared charcoal, silicated carbon, spongy iron, and so on) are not known to be destructive to disease germs, and considering their insolubility, it is almost impossible that they can act as germicides. If, therefore, the use of filters

promotes the purification of water, apart from removing the coarser solid suspended particles, it is by bringing the water into intimate contact with aerated surfaces of the filtering medium which is employed; but this implies that due provision is made (and, as a matter of fact, it is not generally made) for renewing from time to time the efficiency of the said medium by freely exposing it to the air. In the absence of such a provision, the offensive matter abstracted from the water accumulates in the filter and chokes it, and unless it is removed from time to time, water may be rendered impure, instead of becoming purified by its passage through the filter. It has been contended by some, that, by the use of a very finely divided solid medium, even the minute bodies of germs can be arrested in filtration; but this is a matter that calls for practical demonstration, and which certainly cannot be considered proven.

In the chemical examination of waters regard is had not only to suspended matters, hardness, and to the determination of the amount of organic matter in the filtered water, but also to the presence of chlorine, ammonia, nitrites and nitrates. A hard water is understood to mean a water which destroys much soap before a lather is produced in washing operations; the destruction of soap arising from the formation of insoluble salts by the combination of the fatty acids of the soap with the lime and magnesia present in the water, and it is not until these mineral salts have become exhausted that there is produced a lather. As already explained, this hardness arises

from the collective presence of the dissolved matters, including mineral salts, organic substances, and carbonic anhydride.

For softening very hard waters, which owe their hardness, in part, to carbonate of calcium held in solution by the agency of carbonic anhydride, the process originally devised by Dr. Clark, and improved by Mr. Porter and Mr. Atkins respectively, is often employed. The process practically consists in the use of lime either as a filtering medium, or added in the form of milk, by which means the carbonic anhydride enters into chemical combination with the lime to form insoluble carbonate of calcium, and, as a further consequence, some of the dissolved carbonate of calcium is precipitated from the water.

Water may be, also, softened by boiling; the decrease in hardness thus produced is termed the "temporary hardness," while that which remains is styled "permanent hardness"; together they equal the "total hardness" of the water. The "temporary hardness" is due to the presence of carbonic acid, which escapes upon boiling, and to that amount of carbonates of calcium and magnesium which is at the same time deposited out of the solution in which it was previously dissolved by the agency of the carbonic anhydride; so that softening by boiling, resembles softening by means of lime, as in Clark's process.

Chlorine is present in water chiefly in the form of common salt, but it is of importance to determine the quantity, since it may indicate existing pollution with sewage which contains a large proportion of

chlorine. The amount present in good waters varies from 0·22 part to above 5 parts per 100,000, and represents common salt dissolved out of the air and soil by rain. Urine contains about 500 parts of chlorine per 100,000 parts, and 58 samples of sewage from midden and water-closet towns were found by Frankland * to contain an average of 11 parts per 100,000.

Ammonia, when found present in water in any considerable proportion, is supposed to indicate the presence of animal matters in the earlier stage of decomposition. In rain-water collected in the country, the proportion of ammonia is about 0·03 part, whereas town rain-water may contain as much as 0·21 part per 100,000; this larger quantity is dissolved from the air. The average amount in river water is about ·01 part per 100,000. In sewage, the ammonia varies from 2 to 10 parts per 100,000.

The nitrates and nitrites found present in waters are derived from the ammonia formed at an earlier stage, by oxidation; or they may be produced directly from nitrogenous organic matter, as explained in an earlier chapter. Rain-water may contain about ·04 part of nitrogen in the form of nitrates per 100,000, but when collected in towns the quantity is often much greater. Frankland puts down the average quantity present in upland surface waters at ·009 part per 100,000. Thames water contains about 0·2 part nitrogen (combined in the form of nitrates and

* "Water Analysis" (Voorst), p. 19.

nitrites) per 100,000 parts, whereas from the deep wells in the chalk, the quantity rises to 0·426 part. No doubt the amount of nitrates found present in deep well water, often represents previous sewage contamination, but it also indicates the purification that has taken place by oxidation during the filtration of the water through the chalk hills.

Surface wells often yield water which is fouled by recent drainings from cesspools, cultivated land, and refuse matters.

By the logical use of the results obtained from the analysis of waters, combined with a knowledge of their history, it is not difficult for chemists to form a sound judgment as to whether they are or are not fit for drinking use, notwithstanding all that has been said to the contrary by engineers and biologists.

If chemists cannot pronounce positively concerning the absence or presence of disease germs in water, they can at least ascertain from its composition and history, whether it is likely to contain them or not. Engineers can do nothing in this direction, and biologists cannot provide a better test of the purity of water.

The following analytical figures, showing the chemical contents of various waters, are extracted from tables given in Frankland's treatise on water analysis, to which reference has been previously made :—

TYPICAL ANALYSES OF WATER. PARTS PER 100,000.

Description.	Total Solids.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Chlorine.	Hardness.		
							Temporary.	Permanent.	Total.
Rain.									
Rothamsted . .	2·16	·062	·007	·027	0	·10	...	...	·8
London	2·76	·383	·040	·210	·008	·50	...	1·1	1·1
Deep Well.									
In Devonian rocks and millstone grit . .	32·68	·068	·012	·005	·294	2·70	8·8	8·6	17·4
In magnesian limestone . .	61·14	·076	·030	0	1·426	4·31	16·9	26·9	43·8
In chalk below London clay .	78·09	·093	·028	·048	·068	15·02	9·7	8·7	18·4
River.									
Thames	28·03	·201	·033	·0006	·210	1·73	...	...	20·4
Lea	27·82	·128	·023	·0004	·201	1·77	...	...	20·9
Shallow Well.									
Twickenham . .	82·08	·739	·093	·740	2·708	7·8	22·5	21·8	44·3
Tottenham . .	130·44	·108	·053	·002	3·974	8·4	35·2	39·8	75·0

AVERAGE COMPOSITION OF UNPOLLUTED WATER. PARTS PER 100,000.*

Description.	Total Solids.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrites and Nitrates.	Chlorine.	Hardness.		
							Temporary.	Permanent.	Total.
Rain-water . .	2·95	·070	·015	·029	·003	·822	·4	·5	·9
Upland Surface Water . . .	9·67	·322	·032	·002	·009	1·13	1·5	4·3	5·8
Deep Well Water	43·78	·061	·018	·012	·495	5·11	15·8	9·2	25·0
Spring Water . .	28·20	·056	·013	·001	·383	2·49	11·0	7·5	18·5

* To convert parts per 100,000 into grains per gallon multiply by seven, and divide the product by ten. To convert grains per gallon into parts per 100,000, multiply by ten and divide by seven.

CHAPTER VI.

SEWAGE: ITS DISPOSAL AND TREATMENT.

THE sewage of different towns varies in composition according to the system of drainage employed and the amount of water supply. In some towns a "separate" system of drains is employed for sewage proper, the rain-water which is collected from the housetops and streets being drained off quite apart, and discharged into the nearest watercourse without treatment. There can be no objection to this proceeding provided either that the said watercourse is not utilised as a source of water supply for drinking purposes, or that the water becomes purified (by the agencies described in the last chapter) before it is abstracted for distribution. This separate system of drainage is to be commended since, when used, the sewage from any one town is of tolerably constant composition and bulk, and the total quantity to be dealt with is much less than in those cases where rain-water is admixed with the sewage and carried off in the same channels. It will be readily appreciated that a plan of treating sewage adapted to a given quantity of a given composition is often not applicable to the same quantity of impurities con-

tained in a much larger bulk of liquid; indeed, as a matter of fact, it often happens that in times of flood the sewage of towns where the separate system is not used, cannot be purified for this reason. Moreover, the expense attending the purification or the utilisation of sewage is very much in proportion to the bulk to be dealt with, and this consideration is made all the more important by virtue of the fact that the cost of sewage works has in many cases exceeded the whole rateable value of the districts immediately concerned.

Before proceeding to describe the various methods of dealing with sewage, it will be well to make ourselves acquainted with its general character and chemical composition.

Primarily, of course, it contains human excrements, soap-suds, hair, and the impurities removed from human bodies, dwellings, and the streets of towns, by general cleansing operations. These several constituents are contained partly in solution and partly in suspension in a great volume of water, which is universally employed as the carrying agent to effect their removal.

An average healthy man excretes by the kidneys about 50 ozs. of water per day, and in this solution there are dissolved about 500 grains urea (CH_4N_2O) and about 10 to 12 grains of uric acid ($C_5H_4N_4O_3$); other constituents, amounting to from one-third to the same quantity of the urea present, include common salt, chloride of potassium, phosphates and sulphates of potassium, sodium, calcium, and mag-

nesium. Urine also contains small quantities of other nitrogenous organic matters, besides urea and uric acid. The phosphoric acid amounts, on an average, to about 54 grains, per man, per day.

Of these various constituents, the nitrogenous organic principles are considered to be by far the most valuable from a manurial point of view; but, unfortunately, urea, the principal of them, is rapidly decomposed in the sewage by a process of fermentation, into carbonic anhydride and ammonia, thus—

$$CH_4N_2O + H_2O = CO_2 + 2NH_3,$$

and both of the products, being gaseous, escape more or less from the solution, and are lost in proportion.

Fæces represents the undigested and altered portions of the food which have refused absorption; like urine, its quantity and composition, therefore, necessarily vary with the nature and amount of the food as well as other circumstances.

The amount of water contained in fæces varies from 73 to 75 per cent., and the solid matters (dry at 100°C.), therefore, amount to from 27 to 25 per cent., upon an average of quantities ranging from 17 to 31 per cent. Little nitrogen is present in fæces, Dr. Edward Smith having stated that, on the average, the daily elimination of nitrogen by the bowels amounts to about 46 grains. The quantity of fæces yielded by a healthy adult, varies from 5½ to as much as 8 ozs.; but taking men, women, and children collectively, an average of 4 ozs. per day may be taken as approximately correct.

Fæces generally contains but small quantities of

salts, consisting of phosphates of calcium, magnesium, sodium, and potassium. Albumin is met with in a soluble form, and in certain diseases (cholera and typhus) the proportion found present is considerable. The bulk of organic matter present in fæces is represented by the altered biliary substances, fat, starch, cellular and muscular fibres, etc. Playfair found, in a sample of fæces which he examined, as much as 15 per cent. of nitrogen and 45 per cent. of carbon, and I entertain a strong conviction that even the solid parts of sewage are not so valueless as they are often stated to be.

Curiously enough, no paper, it is said, is ever seen in the sewage of London at the outfalls, so that it must become reduced to an impalpable state of division *en route*, or else be decomposed in the sewage.

The following analyses of sewage are taken from Frankland's work on water analysis (pp. 115 and 118) :—

Description.	Total Solids.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Chlorine.	Suspended Matter.		
						Mineral.	Organic.	Total.
Tunstall . .	114·40	4·858	1·692	4·300	14·15	18·12	34·36	52·48
Crewe . . .	98·08	5·014	1·780	1·65	16·0	83·72	262·08	346·00
Fresh sewage: average from 16 water-closet towns . .	72·2	4·696	2·205	6·703	10·66	24·18	20·51	44·69
Fresh sewage: average from 15 midden towns . .	82·4	4·181	1·975	5·435	11·54	17·81	21·30	39·11

Upon the estimate that each head of the population (taking men, women, and children collectively) gives 4 ozs. of fæcal matter per day, London, with its population of nearly 4,000,000, yields daily 446 tons of fæcal matter, and taking this to contain 75 per cent. of moisture and 25 per cent. of dry solid matters, it is seen that above 111 tons of dry fæcal matter are poured into the Thames daily at Barking and Crossness. This amount of impurity is, of course, greatly increased by the heavier solid matters that are contributed by the street drains, and the whole quantity is contained in a bulk of liquid measuring about 170,000,000 gallons.

Of this quantity that which is discharged at Barking is collected from the London area north of the Thames, measuring 53 square miles, and is temporarily received in reservoirs of 9½ acres, the capacity of which is 35,000,000 gallons, or 5,600,000 cubic feet. South of the Thames, the London area is 66 square miles, and the sewage is collected at Crossness in reservoirs of 6½ acres, which are capable of holding 25,000,000 gallons or 4,000,000 cubic feet.

Thus, in the course of a year, the lower Thames will receive about 60,000,000,000 gallons of sewage, in which the amount of suspended matter was estimated by Dr. Frankland, in 1879, at 1,354,000 tons.

At high water time, the sluice gates of the reservoirs are opened for four hours during the ebb, and the sewage is thus conveyed into the tide-water. Some of it is thereby carried out to sea, but a large quantity, and perhaps the bulk, only travels a certain distance

down the river, and is borne back again by the next tide, and some of it reaches up the river even as far as Chiswick. The fact is, that the volume of the river is insufficient to carry away such an enormous quantity of sewage.

A large proportion of the heavier parts of the solid matters, is deposited upon the bed of the river, extending up to Chiswick and down to Southend, and the river between these places is converted into a great sewer, which, in hot weather, is seething with putrefaction.

So great was the nuisance caused in the past summer that the outcry which occurred was but natural and perfectly justifiable, more especially since the country was then threatened with an attack of cholera, which disease was raging in the south of France and Italy. The result of this outcry was that large quantities of chloride of lime and permanganate of potassium were, at first, thrown into the river, and later on, mixed with the sewage as it was discharged; but such a proceeding on the part of the Metropolitan Board of Works could only be expected to mitigate, in an incomplete measure, the nuisance caused by the emission of gases from the putrefying sewage, and that at a very great cost. The quantity of chemicals thus employed was wholly inadequate to oxidise or destroy, in any chemical sense, the enormous mass of organic matter contained in the sewage, and, indeed, the effect was confined to the deodorisation in some measure of the ready-formed products of putrefaction, including

gases containing sulphuretted hydrogen, etc. The cost of such a proceeding would be much too great, and the effect far too little, to warrant anything like its regular adoption. The sewage of London demands chemical treatment, and only the clear effluent should be discharged into the Thames at Barking and Crossness; or failing that, the whole quantity should be carried out to sea, if the metropolis is to be rid of one of the greatest nuisances with which it is at present afflicted.

Mr. Phillips Bevan* is of opinion that the only plan, and the cheapest one, of dealing with London sewage, is to convey it across the Essex marshes to Foulness Island, a little to the north of Shoeburyness, and there, if possible, cast it into the German Ocean. Land is cheap, and space is of little account, at Foulness or Wallasca Islands, and Mr. Bevan thinks that if our boasted scientific knowledge is worth anything, it should enable the proper authorities to convert the useful parts of sewage into a good practical manure in which a brisk trade could be done.

For my part, I agree very largely with Mr. Bevan, but I go further, and venture to express the opinion, notwithstanding all past discouraging experiences, that a reasonable sum of money expended on the spot in experimental work, would enable chemists to make other valuable commercial commodities from sewage in addition to manure.

* *The Sanitary World*, August 30th, 1884.

One of the greatest difficulties of adequately dealing with sewage, lies in the enormous bulk to be operated upon, and it is therefore reasonable to suppose that could some simple mechanical appliance be devised by which a considerable proportion of the clearer liquid could be drawn off and separated from the more solid parts, it would greatly assist in the efficient treatment of sewage. Such clear liquid need not necessarily be passed directly into a watercourse; it could be first distributed over a considerable tract of land, for which it would serve as a useful manure, and by which it would be efficiently filtered and greatly purified.

Sewage passes very rapidly into a putrefactive state, and the gases that are generated in sewers are capable of producing a peculiar kind of fever; but whether the illness is to be regarded as the direct effect of inhaling the mixed chemical gases, or as an expression of the consequence of inspiring a micro-organism whose reproduction in the human body specifically causes the disease, is not known to medical men, who are, however, perfectly familiar with the illness.

The methods of purifying sewage which are at present in use depend either upon filtration through soil (irrigation) or upon the precipitation of the solid parts by the agency of added chemicals.

In what is called broad irrigation, sewage is distributed over the surface of drained and cultivated land, by which means the solid parts are arrested, and the fluid part gradually percolates through the land,

and is finally carried off by the natural or artificial drains. The fluid part, however, does not merely soak through the land, but its constituents are subjected to oxidation in the process.

This oxidation is carried on by the agency of micro-organisms, as fully explained in an earlier chapter, and one chief direction in which it occurs is that of so-called nitrification, to which reference has also been made, already, in some detail. The solid parts which are left in the soil are also attacked, and gradually succumb to the influences of hydration and oxidation, yielding as products, substances which afford food to the plants growing upon the land.

Of course, there is a limit to the capacity of oxidation, and so the land has to be divided into plots, which are successively worked, care being taken that too great a tax is not thrown upon the land, as in that case it becomes choked, and oxidation does not proceed actively, as it should do.

"Intermittent downward filtration" differs in no wise from broad irrigation except in the fact that the land is drained to a greater depth, and so a greater quantity of sewage may be applied to a given surface of land, which, however, is not worked continuously, but, as in the other case, successively in plots. In the periods of repose the soil is supposed to become recharged with oxygen, but it must not be forgotten that the oxidation which is carried on does not altogether result from the mere contact of oxygen with the organic matters, but is, at least in part, the result of the vital actions of millions of micro-

organisms which utilise the oxygen which nature so bountifully supplies near at hand in the adjacent soil.

The following figures, illustrating the purification of sewage by irrigation, are taken from a table given by P. F. Frankland in a recent paper on Thames water * :—

Description of Process.		Average percentage of dissolved organic pollution removed.		Average percentage of suspended organic pollution removed.
		Organic Carbon.	Organic Nitrogen.	
Intermittent downward filtration	Best result . . .	88·5	97·5	100
	Worst result . .	32·8	43·7	100
	Average result. .	72·8	87·6	100
Broad irrigation	Best result . . .	91·8	97·4	100
	Worst result . .	42·7	44·1	84·9
	Average result. .	68·6	81·7	97·7

These results prove that, practically, it does not much matter which kind of irrigation be used, the choice being determined by local conditions, such as the price of land. On the whole, probably, considering the expense of draining land to the greater depth required for intermittent downward filtration, the ordinary process is to be preferred.

According to M. Lefeldt, an acre of land is required for the excreta of every twenty to thirty-five persons; but even if that quantity of land would serve for each hundred persons, the total acreage thus required is far in excess of the available quantity. Moreover, it has been pretty well established that the putrefactive

* *Soc. Arts Journ.*, vol. xxxii., p. 433.

decomposition of sewage in soils, gives rise to the production of malarial and parasitic diseases when it takes place near towns, and that the solid organic matters, after a time, form a solid cake upon the land, which gives off an offensive and dangerous effluvia. Again, the subsoil water is liable to be charged with decomposing matters resulting from the sewage, and Pettenkofer is not alone in his opinion that there is no more fruitful source of disease than such a subsoil water which is constantly changing in its level.

The mere fact that in this country, at least, the available land is insufficient for the disposal of sewage by irrigation, is sufficiently condemnatory of the process as an exclusive means of utilising sewage. London alone would require above 200,000 acres, and when it is reflected that some classes of soil are not suitable for irrigation, and that great expense has to be incurred in preparing the land by drainage and otherwise to receive sewage, it becomes apparent that for these and local reasons, irrigation does not nearly supply the want that is experienced.

At the same time, it is to be clearly understood that given suitable land, of sufficient extent, and in dry weather, we can by irrigation very completely purify sewage. This is proved by the analytical results obtained by Dr. R. Angus Smith upon the examination of the effluents obtained from sewage by different processes, and communicated to the Local Government Board in 1879.*

* See *Chem. News*, vol. xli. p. 50.

I shall not attempt to give an account of the many chemical processes that have been patented for the treatment of sewage, but shall be content with describing the so-called A B C process, and a few of the other more prominent ones that are now in use or have been suggested.

The A B C process of the Native Guano Company is in work at the present time at Aylesbury and at Wellington College. To the sewage, as it is admitted into the works by channels, is first added a mixture of ground clay, charcoal, and blood, previously made into an emulsion with water, and at a later stage, a solution of sulphate of aluminium is run in. The particles of clay assimilate the suspended organic matters of the sewage, and when the blood albumin becomes coagulated by the action of the alum solution, the whole solid matters become entangled or enveloped in the meshes of the coagulating substance, and are deposited to the bottom of the tanks through which the treated sewage slowly flows. The clay is also stated to enter into combination with some of the ammonia present in the sewage, and the charcoal is supposed to absorb a further quantity, and to exercise a deodorising influence. The action of the alum solution in precipitating the clay and blood is promoted by the alkaline nature of the sewage, which causes the separation from the sulphate of aluminium of gelatinous flocks of alumina. As the mass of treated sewage flows through two successive tanks, it deposits practically the whole of the suspended matters originally contained in the sewage, together with the added

chemicals, and the effluent passes away to the river (at Aylesbury) clear, purified to a great extent, and nearly odourless.

The following analyses are published by the Company:—

Analyses.

RESULTS IN GRAINS PER GALLON.

Suspended Matters.	Sewage.	Effluent Water.							
	Dr. Wallace.	Dr. Wallace.	Dr. Angus Smith.	Dr. Tidy.	Professor Way.	Dr. Keates.	Professor Wanklyn.	Dr. Wallace.	Standard of Rivers Pollution Commission.
Organic . .	24·9	traces.	—	·04	—	—	—	none	·70
Inorganic .	12·9	„	—	·18	—	—	—	„	2·10
Total .	37·5	„	—	·22	—	—	—	„	2·80
Free Ammonia	5·18	2·73	·714	·60	1·12	1·75	·61	1·19	no standard
Albumenoid do.	·58	·12	·049	—	·07	·18	·03	·112	·21
Oxygen required to oxidise the organic matter	2·17	·91	—	·25	—	—	—	·23	—

In a report published by Dr. Angus Smith in 1879, at the request of the Local Government Board, he found, taking samples over a month at unexpected times, that the organic carbon in the dissolved organic matter present in the sewage operated upon, was reduced by the process from 6·76 to 0·63, or by 90 per cent.; the albumenoid ammonia was also reduced from ·66 to 0·07, or very nearly 90 per cent., and the free ammonia from 4·00 to 1·02, or 75 per cent.

These analyses indicate that beyond the precipitation of the suspended organic matters, some part of the dissolved organic matters is removed from the sewage by the process.

The precipitated sludge is pumped from the tank, deprived by pressure of its superabundant water, and further dried by artificial heat, till it attains the consistency and appearance of dry earth, in which state it is sold to farmers and gardeners as Native Guano, and judging from the statements published in a pamphlet by Mr. Crookes,* who was for some years scientific adviser to the Company, and the reports from farmers and others, the product is a valuable manure. It is not so valuable when judged by the somewhat arbitrary standard in common use by chemists, as, according to this standard, value is attached only to the contained ammonia and phosphoric acid. But it is questionable how far this standard is a reliable one as applied to the manurial value of a product, for it ignores to a large extent its collective organic nature and its physical condition.

Among other processes officially investigated by the late Dr. R. Angus Smith was that employed at Coventry, which consists of precipitation by alum and iron salts, and lime, followed by irrigation of the effluent. In consequence of this double system, the water eventually obtained from the sewage is

* "The Profitable Disposal of Sewage." By W. Crookes, F.R.S.

of a very high quality, as the following figures demonstrate :—

	Organic Carbon.	Free Ammonia.	Albumenoid Ammonia.	Nitric Acid.	Total Solids.	Parts per 100,000 contained in the water.
Crude Sewage . .	11·33	2·58	1·70	None	99·0	
Filtered Effluent .	1·418	2·40	0·245	None	71·0	
Effluent after irrigation	0·587	2·12	0·205	1·22	77	

Another mode which has been proposed for dealing with sewage, consists in heating it with milk of lime, condensing the ammonia that is evolved, and separating and pressing the sludge which remains behind. This sludge has little value (in common with all lime precipitates) as a manure, and it would hardly pay to burn it with the view of regaining the lime in a caustic condition for use over again.

"Hanson's process" consists in treating the sewage with lime and alkali waste. It is said to be in use at Aldershot, and, judging from the analytical results furnished by P. F. Frankland, it is not so effective as the A B C process.

The following are the results referred to :—*

RESULTS OF ANALYSES IN PARTS PER 100,000.

	Dissolved Matters.						Suspended Matters.		
	Total Solid Matters.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Total Combined Nitrogen.	Chlorine.	Mineral.	Organic.	Total.
Raw Sewage .	132·72	7·441	2·234	0·90	2·975	5·7	4·96	44·70	49·66
After Treatment	120·16	4·777	1·802	0·80	2·461	7·1	2·36	—	—

* *Journ. Soc. Arts*, vol. xxxii., p. 434.

In the process devised by the late General Scott, the idea of obtaining a valuable manure from sewage was abandoned, and the total precipitate obtained by the addition of lime, or lime and clay, is collected, dried and burned, in order to make cement. Precipitation by lime, however, yields an effluent which, from its comparative impurity and alkaline character, soon passes into a state of putrefaction, and the lime which passes in solution is fatal to the fish contained in river water.

The following analyses by Dr. R. Angus Smith show what sort of an effluent is obtained from sewage by precipitation with lime :—*

	Organic Carbon.	Free Ammonia.	Albuminoid Ammonia.	Nitric Acid.	Total Solids.
Crude Sewage (Burnley) . . .	20·33	1·45	1·20	None	197
Effluent	3·737	1·33	0·305	1·2	54
Crude Sewage (Birmingham) .	20·44	2·70	1·05	None	177
Effluent from Settling Tanks .	4·09	3·22	0·66	2·13	100·5
Effluent after irrigation . . .	2·303	1·275	0·21	1·19	112·5

Certain experiments which were made by Dr. Angus Smith led him to think that by driving air through sewage matter, in order to produce oxidation, not only would nitrates be readily produced, but the excess of air would be offensive to the microzymes, notwithstanding that some air is necessary for their activity. Further experiments upon the aeration of sewage showed that in all cases putrefaction was delayed by aeration, and that ammonia

* *Chem. News*, vol. xli.. p. 51.

is contained in the air that has passed through the sewage. He continues, "The dissolved oxygen also recovers itself in the aerated specimens better than in the non-aerated. This shows that aeration not only prevented putrefaction, but prevented also the chemical action consequent upon it. It had, in fact, to a large extent, and for a considerable time, rendered the organic matter inert, or nearly so. Nitrates are also formed more readily in the aerated than in the non-aerated specimens." In the same communication,* Dr. Angus Smith quotes the results obtained by M. Lauth, who had conducted similar observations (see *Compt. Rendus*, lxxxiv. 617-620). M. Lauth filled two bottles, one with ordinary sewage, and the other one with sewage saturated with air, and then placed both on one side to watch the results. The non-aerated sewage soon became black and offensive, whilst the aerated sewage was inodorous after two months. He also found that lime had an effect similar to that of air, and he studied the effects of liming and aerating the sewage. The following analytical results were obtained by him:—

	Insoluble Nitrogen.	Soluble Nitrogen.	Nitrogen as Nitric Acid.	Nitrogen as Ammonia.	Total Nitrogen volume.
Before Aeration .	14·70	20·65	1·176	8·4	38
After Aeration. .	8·05	26·95	1·122	14·0	38
Treated with Lime .	10·15	25·55	2·60	18·20	
Treated with Lime and Aerated .	6·65	28·87	2·12	21·35	

It is seen from these results that the process of

* *Sanitary Record*, vol. v., p. 159.

liming sewage, as also that of aerating it, both result in the increased production of ammonia and nitrates and the prevention of putrefaction.

According to M. Lauth, sewage contains from 4 to 7 grains ammonia to the gallon, but, unfortunately, this amount of ammonia, though great in itself, is insignificant in comparison with the amount of water in which it is contained; hence the difficulty in extracting it.

The late Dr. James Young (of Kelly) found that by the distillation of 5 per cent. of the sewage at 100°C. the bulk of the ammonia was obtained in the distillate; while by increasing the temperature and pressure, it still increased, until at 70 lbs. pressure almost all the ammonia could be obtained by distilling over 1½ per cent., the expulsion of it being accelerated by the injection of a small quantity of air.

Later on, he found that a low temperature was desirable, and that by the use of an exhausting air-pump, and at a temperature of 26·6° C. (80° F.) sewage containing 5 grains ammonia per gallon, could be almost entirely deprived of it in a few minutes. Instead of passing air through the sewage, it was sufficient to pass steam at a very low tension, and consequently with an enormous bulk "When he passed the sewage down a coke-filled tower, which was rendered vacuous,* and which gave, from a great expansion of surface, a ready means of evaporation,

* Vacuum of half-inch or 12·7 mm. Mercury.

he considered that he had put the problem in a satisfactory form."

Whether any commercial results will follow from these various experiments remains to be seen.

Dr. Angus Smith * calculated that, if only one grain of ammonia could be taken out of each gallon of sewage, there would be obtained from 1,000,000 gallons about 140 lbs. Now, the Glasgow sewers alone convey daily 50,000,000 gallons, and this quantity upon the same calculation would yield 7,000 lbs. ammonia, which would give about 1,100 tons per annum, equal to a value of nearly £60,000, while the London sewage upon the same basis of calculation would yield ammonia equal in value to about £200,000.

With the view of reducing the total volume of sewage to be dealt with, and thus concentrating its valuable constituents, it was proposed to provide London in 1854 with the separate system mentioned at the beginning of this chapter, but the area is so immense, the cost would be so great, and the disturbance so enormous, that the suggestion has been considered by high authorities to be hardly practicable. It is generally admitted that the quantity of sewage proper (that is to say, the quantity that would flow from the house and general drainage without any mixture with rain or spring-water) is fairly measured by the amount of the water supply, which is given in Mr. Baldwin Latham's table at 144

* *Sanitary Record*, vol. v., p. 159.

million gallons *per diem*. So that the difference between this quantity and the total quantity actually discharged from London, viz., 170 million gallons, amounts to about 26 million gallons, and represents rain and spring-water accidentally mixed with the sewage.

In concluding the study of the water-carriage system of removing sewage, we may sum up as follows :—

1. Where practicable, a separate system of drains should be employed for sewage proper and rain-water.

2. Rain-water thus collected is necessarily polluted with organic refuse, but it may be adequately purified without danger to the public health, either by filtration through a properly drained porous soil, or by natural oxidation in a running stream of sufficient volume.

3. Sewage, whether admixed with rain-water or not, should be so dealt with (by screening, subsidence, or otherwise), that the solid parts are removed from the liquid parts. The liquid parts should then either receive chemical treatment, so as to obtain valuable products therefrom, or be used for irrigation purposes, failing or after which, it may be allowed to flow into some water-course of sufficient volume, and preferably one that is not used as a source of drinking-water.

The solid parts of sewage merit chemical treatment, whereby they may be made to yield valuable chemical products, failing which, they should be

treated in a way that will make them innocuous until they are utilised as manure.

If the solid and fluid excreta of human beings, really have the value that is ordinarily attached to them, private enterprise would surely be rewarded (at least in places where the water-carriage system is not employed) for their collection and utilisation. Thus, a small portable apparatus might be supplied to each house, provided with a strainer, whereby the urine would be separated from the solid parts; and this receiver could, by a properly organised system, be collected daily and a clean one left in its place. The receivers containing the excreta should be taken direct to the factory, where ammonia could be profitably obtained from the urine, and the solid parts could be also utilised, either as a source of ammonia and certain salts, or they could be dried and utilised as fuel for distilling the urine. Or again, the excreta collectively could be worked up with other substances into an innocuous and valuable manure ready for immediate application to the soil. On the other hand, if the human excreta be of little value, one of the arrangements for sprinkling the refuse matters with ashes or dried earth should be used, and the resulting mixture should be daily utilised on the spot for gardening purposes, or be carted away daily with the general house refuse. Treated with ashes or earth the urine and fæces in a fresh state are no more dangerous to health when contained in an iron or galvanised iron dust-bin than are the bones and other decomposing vegetable and animal matters

that are stored therein, until they are removed by the local health authorities. All slops should, under such circumstances, be thrown upon the garden or waste land or drained off from the houses to a suitable distance and locality. Cesspools and middenheaps should, under no circumstances, be employed.

Addendum.

Since writing this chapter I have perused the paper on Sewage Disposal * contributed to the Sanitary Institute meeting at Dublin by Professor Henry Robinson. He states that clay land can be utilised for irrigation purposes by digging it out to a depth of six feet, burning it into ballast, and replacing it in layers, interposed with an occasional layer of open alluvial soil, and if well drained, this prepared filtration area will continuously clarify the sewage of 1500 people to the acre. The cost of preparation, however, amounts to from £750 to £1000 per acre, besides which, he adds that the larger particles in the sewage should be first strained off by a process of straining conducted upwards. These separated solids have to be dug into low-lying land.

He also states that open porous land with a good free subsoil, drained six feet deep, will effectually deal, per acre, with the sewage of from 600 to 700 people.

* *Sanitary Record*, October, 1884.

CHAPTER VII.

INFECTANTS AND CONTAGIOUS DISEASES.

ONE of the most important facts to be gathered from history, is the liability of human beings to be attacked by diseases of an epidemic nature. History, from the earliest records to the present day, furnishes more than sufficient proof of this fact. The Sweating Sickness of 1485, as also the Black Plague of London (1499), may be cited in illustration.

It is recorded by Short, the historian, that in 1625 there was a mortality from plague, in London alone, of upwards of 36,000. Then, again, in the years 1635 to 1636 there was a plague mortality of 14,000; while in the years from 1663 to 1665 there occurred in the same city, it is said, between 70,000 and 80,000 deaths.

In brief, from the year 1490 B.C., when 624,000 Israelites were destroyed by plague in the wilderness,* till the recent outbreak of cholera in France and Italy, history teems with the records of wholesale destructions of mankind by diseases of an epidemic character.

* Numb. xi. *Josephus Antiq. Jews.*

The years 1878-79 furnish at least three instances of wholesale infection, viz., the miasmatic fever of Cyprus, which, according to report, placed 25 per cent. of the British troops at that time stationed there, on the sick list; the yellow fever, which occasioned frightful ravages in Mexico; and the plague, which seems to have originated in Astrakhan, and which set all Europe in fear and trembling lest it should be carried westward.

Of one disease alone—viz., typhoid fever—it is on record that nearly 100,000 cases occur annually, and of these about 15 to 20 per cent. prove fatal!

If we consider these facts, and "the almost total impotence of medicine for direct cure, we may indeed consider this a question more for statesmen and governing bodies than for physicians. Nevertheless, it is necessary that the efforts of the former should be guided by such knowledge of the nature and causes of these diseases as the science of the day can afford. Nor is such knowledge less to be desired for the people in general, in order to counteract the baneful effects of ignorance and prejudice." *

With these facts before us, let us now endeavour to ascertain how far science is able to indicate the nature and causes of infectious diseases, together with the means of arresting or preventing them.

In the first place, then, these diseases are naturally divided into three classes, viz., those which depend upon poisons which originate outside the body and

* "The Germ Theories of Infectious Diseases," p. 1. By John Drysdale, M.D. London: Baillière, Tindall, & Cox.

are not contagious; the contagious diseases arising from contagions or specific excitants, which are reproduced in or upon the bodies of the sufferers; and diseases in which the contagion is not so readily transmitted from person to person, but which at the same time is, nevertheless, always derived from a prior case, the poison being carried in the secretions.

As examples of the first class, we may instance malarial fever and septicæmia. In the first of these it is supposed that under favourable conditions, as regards moisture and temperature, vegetable matter undergoes a putrefactive process, resulting in the formation of a specific poison, which, by its reception, or that of the micro-organisms which produce it, in the living body, produces either remittent or intermittent marsh fever. The disease known as septicæmia is really very similar to this in many respects, although there is no doubt regarding the non-living nature of the excitant (sepsin).* For at the outset, the poison itself is produced during the putrefaction of albuminous compounds; and this, when introduced into the blood-system, gives rise to the disease in question.

Both sepsin and the malarial poison are always generated outside the body itself, and neither disease is communicable from one person to another, in the ordinary sense of that expression.

Small-pox, measles, scarlet fever, plague, and

* Consult Dr. Burdon-Sanderson's papers contained in the Reports of the Medical Officer of the Privy Council, etc. No. 8, 1874, and No. 8, 1876.

glanders, etc., are members of the contagious class of diseases. It is said they never originate spontaneously, but are always communicated from one person to another, the specific contagia upon which they depend being evolved from one person, and reproduced in the contaminated organism. In small-pox, the virus is thrown off from the skin; in measles, from the mucous glands of the nose and air passages; in scarlet fever, by the glands of the throat in particular, and so forth. How virus, after transplantation, establishes and reproduces itself, will be our study hereafter. For the moment it is sufficient to recognise the fact.

Of the third class, it appears that the virus of any one disease may be carried in the secretions, and is capable of undergoing development outside the body. Thus in typhoid fever, the contagion is elaborated by or in the glands of the intestines, and hence passes away with the fæces. In these it resides, and may-be partly develops, being ready at any future time to attack those persons who may expose themselves to its influence. Supposing that such infectious matter be not immediately altered or destroyed, its possibility for harm is unlimited; for as the fæces dry, its particles may be carried either into drinking water or the atmosphere, and happy is the man who neither drinks the one nor breathes the other when they are so contaminated!

Now of late years there has sprung up anew in the minds of men a very old theory of disease, but which, to do the new science justice, until recent years

rested upon a most insignificant basis. This theory, which may be said to have originated with the remarkable investigations conducted by Leeuwenhoek in 1683, and in which he discovered the existence of active microscopic organisms, was revived by Henle in 1840, and again in his *Rationelle Pathologie*, in 1853. Although since then the classical researches of Pasteur on Fermentation, and those of Tyndall and others on germ life, have added much to the data, the theory itself has undergone no material change. In 1840 Henle taught that "infection in contagious diseases is caused by living beings, and that scabies is to be regarded as the type of contagious diseases."* To this, Liebig replied that such an opinion was founded on the principle that like effects imply like causes, and he goes on to add, "This is the very principle which for centuries impeded the progress of natural science, and which, even in the present day, leads to so many errors."

Liebig did not deny the existence of parasitic diseases; indeed, he readily admitted that there are many diseases which are caused by parasites which are reproduced in and upon the bodies of animals, and live at the expense of the constituents of their bodies. Scabies (or the itch) is such a disease, and muscardine, a disease to which the silk-worm is liable, is of a similar nature. In truth, there is no lack of examples.

Liebig, however, maintained that excluding para-

* Henle, *Zeitschrift*, ii., 305, and Liebig's "Animal Chemistry," English Edition, 1846, p. 210.

sitic diseases, which naturally require no chemical or any other theory to explain their communication, the true contagious diseases (such as small-pox) depend upon perfectly distinct and different causes. He writes,* "The condition which determines in a second individual, his liability to the contagion, is the presence in his body of a substance which, by itself, or by means of the vital force acting in the organism, offers no resistance to the cause of change in form or composition operating upon it. If this substance be a necessary constituent of the body, then the disease must be communicable to all persons; if it be an accidental constituent, then only those persons will be attacked by the disease in whom it is present in the proper quantity, and of the proper composition. The course of the disease is the destruction and removal of this substance; it is the establishment of an equilibrium between the cause acting in the organism which determines the normal performance of its functions, and a foreign power by whose influence these functions are altered."

In brief, Liebig looked upon fermentation and the true contagious diseases as processes in which a substance in process of change imparts by virtue thereof a disturbance to the equilibrium of the elements of other bodies. Beyond this general definition he did not attempt to define the nature of the contagia, but merely contended that all contagia are not parasites. He adds,† "In the contagion of small-pox, of plague,

* Page 205 of his "Animal Chemistry."

† *Ibid.*, p. 209.

of syphilis, of scarlet fever, of measles, of typhus, of yellow fever, of dysentery, of gangrene, of hydrophobia, the most conscientious observation has not been able to detect animals, or even organised beings at all, to which the powers of propagation could be ascribed."

Nearly forty years have elapsed since these words were written, and although many conscientious and untiring workers have laboured in these paths of investigation, to-day's science can give no better theory of contagion, or better indicate the manner in which the contagia act upon the living body.

The further consideration of this subject, it being one of great dimensions and scope, will be best treated by stating the chief established facts without any discussion, except of some salient features.

Following the discovery made by Leeuwenhoek, there came the researches of Cagniard la Tour and Schwann, by which it was proved that the globules of yeast are living plants which multiply indefinitely under favourable circumstances; since then, it has been established by the researches of Pasteur in particular, and others in general, that the ordinary processes of fermentation are so many instances of a biological reaction manifesting itself as the result of a special force residing in organisms; or, in other words, fermentation is essentially "a correlative phenomenon of a vital act, beginning and ending with it."*

* See Schützenberger's work on Fermentation, p. 39. H. S. King & Co., London.

Indeed, a ferment such as yeast behaves towards a chemical substance such as sugar, just in the same kind of way that a parasite behaves towards the body on which it preys. The two phenomena are correlative and parallel.

As yeast splits up sugar (or rather seems to yield a secretion which does the chemical work), and lives upon it, reproducing itself, so also certain forms of germ life behave towards albuminous compounds as previously explained. The one phenomenon is called fermentation, the other is known as putrefaction.*

The germs which induce putrefaction are ubiquitous, and this is a fact which it will be important to bear in mind hereafter. All the water and air we drink and breathe ordinarily swarm with germs of the three natural groups of the lower fungi,† viz., the mould-fungi, the spreading or yeast fungi, and the fissiparous fungi, or bacteria. These groups comprise a great variety of septic and alcoholic ferment-organisms and monads, and form part of the organic matter of the air, which amounts to one grain in 200,000 cubic inches in the case of purer country air, and to one grain in 8,000 to 10,000 cubic inches of less pure town air (*Angus Smith*).

To understand the infinitesimal size of these organisms, it may be mentioned that Naegeli has calculated each to weigh only the thirty thousand

* See the Author's paper, *Journ. Chem. Soc.*, January 1880.

† Stated by Dr. Drysdale, partly on the authority of Naegeli. See p. 24 of his essay.

millionth of a milligram! "Consequently," writes Dr. Drysdale, "all animals and vegetables on the face of the earth are continually receiving abundance of fungus-germs in the water essential to their existence. Thus, in the air we breathe, in all that we eat and drink, and touch, and lie on, we are continually exposed to the reception of germs. Accordingly, bacteria and various fungi and germs have been detected on all parts of the surface, and of the mucous passages open to the air, and in the organs communicating with the mucous membrane. They are found in myriads on the tongue and in the tartar of the teeth, in the nose and throat, and all through the alimentary canal into which countless myriads are continually poured with our food and drink. Even developed bacteria have been found in the liver and spleen, and in the blood of healthy animals in certain cases; but the germs or spores are diffused through the interstices of the tissues, where under favourable circumstances they may come to maturity, as bacteria are sometimes found in abscesses shut off from the air. They are found also in the perspiration of the axilla, the face, and other parts; also in the fluid of blisters raised artificially. Nay, even, they are found in seeds or ova; the pink mould has been found in the middle of a nut, and the *dactylium soyerium* in an unbroken egg. The cells of plants produce fungi, which fructify within them. In short, we may take it as established that the whole of the higher organisms are interpenetrated perpetually with the germs of the lower fungi, and

these may even develop in small numbers without much disturbance of health."

According to Klebs,* members of the three groups of hyphomyceta, algæ, and schizomycetæ, occur in the animal and human organisms in infectious diseases. The first of these groups requires an abundant supply of oxygen, and as they run their course chiefly on the surface of the body, they are not deemed to be of the greatest importance. The group includes the forms *achorion*, *trichophyton*, *oïdium*, *aspergillus*, and are considered to be the causes of favus, ringworm, thrush, and possibly madura-foot and actinomycosis.

Of the algæ, only one, viz., *leptothrix*, is considered known as a producer of disease. It is supposed by Klebs, not only to give rise to deposits of carbonate of lime in the teeth, but also in the urinary bladder (calculi); and when the organisms attack the teeth, they are stated by Leber and Rottenstein to cause caries.

The schizomycetæ is the most important group, and it comprises two widely different series of forms, viz., *bacilli* and *cocco-bacteria*.

The bacilli consist of threads, in the interior of which permanent or resting spores are found, which, when they become free, develop under the influence of

* "On the Relations of Minute Organisms to Certain Specific Diseases," *Brit. Med. Journ.*, August 13th, 1881. See also "Micro-Organisms and Disease," by Dr. E. Klein, now in course of publication in *The Practitioner*, and an account of the Biological Laboratory at Health Exhibition in *Brit. Med. Journ.*, August and September, 1884.

oxygen into new threads. The splenic disease of cattle is caused by these organisms, so also is hog cholera (Klein), etc. Cholera and yellow fever are also supposed by some to be caused by members of this series.

The second series of the same group consist of *micro-cocci*, which form themselves into short rods, which sprout out, break up by division into chains, and lead again to the production of resting masses of cocci. This series is further sub-divided by Klebs into *microsporina* and the *monadina*, in the former of which the organisms are collected into spherical lumps, and in the latter into layers. The one class is developed in artificial cultivations at the bottom of the fluid, and requires a medium poor in oxygen, while the other genera require much oxygen, and develop therefore on the surface. To the *microsporina* Klebs attributes the septic processes, and also diphtheria, and the *monadina* are believed to produce inflammatory processes, such as rheumatic affections of the heart, kidney and liver affections, and in general, the inflammatory processes which do not lead to suppuration but to the formation of connective tissue, also acute exanthemata (including variola-vaccina, scarlatina, and measles), and infective tumours (including tuberculosis, syphilis, and glanders).

Cohn gives a different classification, and this has been adopted by Klein; but there is no necessity for us to describe it.

Bacteria, generally, are minute organisms, multiplying by fission, and they are composed of protoplasm invested with a delicate membrane. It is this mem-

brane which enables them to resist the action of caustic chemicals. Pasteur, as mentioned elsewhere, divides them broadly into *ærobes*, which require free access of oxygen, and *anærobes*, which grow without free oxygen. They all require food containing carbon and nitrogen and certain inorganic salts. Most bacteria are destroyed by freezing and by drying, but the spores of *bacilli* constitute an exception; they survive exposure to—15°C. All spores are killed by a temperature of 120°C. Many chemical substances are inhibitive to their growth.

The micro-organisms now under consideration, present a remarkable power of endurance, when compared with that of human beings and animals in general, but it must not be forgotten that their type of life is altogether of a different order. Thus, Miquel has cultivated a bacterium which lives and thrives in a medium charged with sulphuretted hydrogen, and it has been well established that growth or multiplication by scissiparity or spore-production, can take place up to 55°C., according to Cohn, or 74°C., according to Van Tieghem.* Already, in an earlier chapter, mention has been made of the experiments made by the late Mr. F. Hatton for Dr. E. Frankland, who concluded that bacteria can be cultivated in an atmosphere of either carbonic oxide, cyanogen, sulphurous anhydride, nitrogen, nitrous oxide, carbonic anhydride, or coal-gas. Mr. Hatton observed that in an atmosphere of air, the organisms

* See paper by F. J. Faraday, F.L.S., *Chem. News*, vol. l., pp. 71—74, 90—93.

present in a meat-solution, absorbed oxygen and eliminated carbonic anhydride. An atmosphere of hydrogen was not affected, and did not apparently affect the bacteria. Cyanogen seemed fatal to the bacteria when in solution in that form, but its decomposition into ammonic salts and azulmic acid was assisted by their presence. Sulphurous anhydride, even when present in the meat solution to saturation, was without influence on the bacteria. Salicylic acid, strychnine, morphine, narcotine, and brucine, Mr. Hatton found to be "without any effect upon bacteria, even when quite large quantities are put into the solution containing the germs." On the other hand, it was noted that phenol, spongy iron, alcohol, and permanganate of potassium destroyed bacteria with great rapidity.* With regard to these experiments, it is to be observed that some of the substances employed are insoluble in meat solutions, so that unless it can be proved that bacteria breathe as do human beings, it cannot be supposed that a mere envelope of gas would prejudice their existence. Further, it must be remembered that the chief function of micro-organisms, so far as has been ascertained, is the destruction by oxidation of organic refuse at large. To accomplish this destruction, oxygen is necessary, and if the bacteria cannot get it in a more ready manner, they are able to decompose comparatively stable substances, and rob them of their constituent oxygen. It would, indeed, appear, from the

* *Journ. Chem. Soc. Trans.* 1881, p. 247.

description and results of Mr. Hatton's experiments, that he actually experienced this fact. Thus, in an atmosphere of carbonic oxide, the bacteria unmistakably decomposed it, or caused its decomposition, utilising its oxygen for purposes resulting in the production of carbonic dioxide; a similar process would appear to have taken place in an atmosphere of nitrous oxide.

Mr. W. M. Hamlet also conducted an investigation about the same time, and it will be interesting to direct attention to some of his results.* He operated upon various solutions for cultivating the bacteria, viz., Pasteur's fluid with sugar, beef-tea, hay-infusion, urine, brewers' wort, and extract of meat, and employed flasks similar to those used and described by Pasteur. Mr. Hamlet confirms the results obtained by Mr. Hatton in respect of the behaviour of oxygen towards bacteria. It does not kill them, but, on the other hand, they make use of it to convert dissolved organic matter into ultimate products including carbonic dioxide. This is strictly in accordance with the known history of putrefaction as worked out by Pasteur. After describing his experiments, he writes, "These results show that amounts of chloroform, phenol, and creosote, varying from ½ to 3 per cent, do not destroy bacteria, although their functional activity is decidedly arrested while in contact with these re-agents." They are subdued in activity, but not deprived of their vitality, which they regain

* *Journ. Chem. Soc. Trans.* 1881, p. 326.

when restored to more congenial surroundings. He continues: "Upon both classes of bacteria, oxygen has a most important action. To the anærobian, oxidation is rapid and fatal as a poison to the higher animals, while the ærobian, less easily oxidised, are resolved by complete oxidation into nitrogen, carbon dioxide, and water."

"We may conclude, therefore, that those bodies which destroy bacteria are those capable of exerting an immediate and powerfully oxidising action, and it seems, after all, but stating a truism to say that (extremes of temperature, of course, excepted) it is active oxygen which must be regarded as the greatest known enemy to bacterial life, whether from the action of chlorine, nitric oxide, ozone, or peroxide of hydrogen. It also follows that these bodies are the best disinfectants."

Without entering further upon this study, it may be taken for granted that micro-organisms exhibit a wonderful power of endurance. They may be strongly heated and nearly frozen, dried, and the matter containing them pulverised, and still they live; they may be exposed to some gases, or cast into certain chemical solutions, and yet they are not killed. On the other hand, it is far more important to ascertain under what conditions they can be influenced or are killed. They are destroyed by a sufficiently high temperature; they can be killed by a process of starvation adapted to the peculiarities of their life-history, and many chemical re-agents either arrest or divert their functional activity or kill them outright.

It is to the action of such germ life that the germ theory attributes all the contagious diseases to which man is liable!

It will be seen that the ubiquity of germs is a very telling argument against this theory when applied in this its widest sense, and it may be safely said that its upholders, in their zealous search for germs, and hoping to find them associated with infective inflammations and contagious fevers only, have indeed found them everywhere—much to their discomfiture. If it be true that germs, alone, constitute contagium-vivum, then it can no longer surprise us that infectious disease is of common occurrence. On the other hand, it devolves upon the germ-theorists to explain the escape of any one individual from such an all-pervading contagium.

The truth is, in spite of all that has been said and written on the side of the germ theory, its very advocates admit that as far as scarlet-fever, small-pox, measles, and the rest of the principal contagious fevers are concerned, "their connection with pathogenic organisms is, as yet, a matter of pure inference" (*Roberts*).* Nay, more, it is scarcely a matter of inference; it is one of pure hypothesis. It must be obvious to all, that if the true contagious fevers are attributable to specific germs, then small-pox, scarlatina, and typhus should originate spontaneously, instead of which they seem to be entirely dependent

* "Reports on the Life History of Contagion." By Dr. Braidwood and Mr. Vacher. Also Dr. Roberts' address, *British Medical Journal*, 1877.

upon previous cases. This is an insurmountable difficulty to practitioners, but the theorists have invented a way out of it.

It is true that the constant presence of a particular species or genus of germ may be microscopically demonstrated in the case of certain diseases, but it is also true that the same observation may be made in cases where there is no disease. For instance, Dr. T. R. Lewis, of the Army Medical Department, finds* that the comma-shaped bacillus, identical in size, form, and re-action with dyes, with that described by Koch as the specific cause of cholera, is present in the secretions of the mouth and fauces of perfectly healthy persons: what is more, Klein is stated to have swallowed the bacillus and to have experienced no result.

The theorists evade this difficulty by crediting certain of these low forms of life—not distinguishable by appearance or ascertained life history from others known to be harmless—with pathogenic powers. That is to say, they view them as physiologically distinct, without sufficient warrant for so doing.

Thus, it is urged against the observations of Dr. Lewis that the mode of growth of the comma-shaped bacillus in gelatinised meat infusion, should be relied upon as affording a means of distinction between the innocent germs and the pathogenic organisms of Koch, but it seems to me rather to rest with Koch to prove that this suggested distinction has a real

* *British Medical Journal*, September 20th, 1884.

existence, although, failing that, it is to be hoped that Dr. Lewis will, himself, make this proposed test of identity a matter of experimental observation.

Against the germ theory, it may be further urged that it is practically impossible to perform an inoculation experiment in which, with certainty, only one specific organism is employed, and that in a state free from any secretion, or other matter which may possibly constitute the contagium itself.

It must be admitted, on the other hand, that there are one or two special diseases which, it is now generally and confidently asserted (and not without considerable reason) are caused by low organisms. To these a little attention must be devoted before we proceed to study another doctrine, which, in some respects, is of a more acceptable nature.

Dr. Obermeier, of Berlin, was the first to observe spiral organisms in the blood of patients suffering from relapsing fever, and since then the observation has been often repeated. The disease is not contagious in the ordinary sense of that word, but may be communicated by inoculation with the blood of a patient, provided the blood be taken during the paroxysmal periods, when spirilla are present; they are absent at the crises (a remarkable fact, in itself, and affording good reason for doubt as to the true cause of the disease). From this it is concluded that the spirilla constitute the infectant. It is admitted that ocular evidence of the germ in question is all but absent, and all attempts to cultivate the spirilla out of the body have failed. Whether, therefore, the

disease is, after all, not communicated by some other constituent of the blood, is unascertained.

In 1855, Polender discovered minute staff-shaped bacteria in the blood in cases of splenic fever. Since then, it has been ascertained that they also exist in the spleen, the lymphatic glands, etc., etc. Cohn and Koch having devoted particular attention to this subject, they have concluded that *bacillus anthracis* is the true virus of the disease.

Here, again, the contagium is communicated by actual contact of the blood or other exudations of a diseased subject, but it is not communicated by placing animals in the closest proximity to the diseased ones ; in short, there is no infection through the air. It is also to be observed that the infective power of the blood disappears on the appearance of putrefaction. It is not necessary to go through the life history of this bacterium; it will suffice to state that Koch seems to have proved beyond cavil that, in suitable nutriment, spores are formed, and these reproduce the rod-bacilli, which are then competent to produce splenic fever in living animals. Whether, however, this result is actually brought about by the germs in question, or by anything accompanying them, is not quite clear. The test was a crucial one ; but, as admitted by more than one well-known pathologist, there exists some reason to doubt whether Koch obtained the bacillus quite free from other possibly poisonous matter.* The

* See Dr. Drysdale's Essay, p. 16. Also my "Animal Chemistry," p. 438.

reason is the greater since Professor Cohn could not distinguish *bacillus anthracis* from *bacillus subtilis* (of the butyric fermentation) in a morphological sense.

More recently, Klein, by an investigation of infectious pneumo-enteritis in the pig* (pig-typhoid, so called), came to the conclusion that this disease is caused by a microphyte admitting of artificial cultivation outside the body, and which, when so cultivated, even to the eighth generation, is capable of producing the original disease in a healthy pig. No one can question the extreme care and skill with which these experiments have been conducted; but at the same time there exists the doubt (as in splenic fever) as to whether the disease is really caused by the germ itself, or is owing to some product to which either it, or some secretion from it, gives rise.

To illustrate the meaning of this argument, it will be convenient to recall the facts concerned in septicæmia. In that disease the poison has been proved not to consist of germs, but of a non-living substance elaborated by micro-organisms in a proper medium; and so similarly, for aught that is known, both splenic fever and pneumo-enteritis of the pig may be produced.

The position may be summed up in a few words.

If it be admitted that splenic fever and so-called pig-typhoid are directly caused by microphytes, then I contend that such diseases must be taken out of the class of ordinary contagious diseases, and be

* Seventh Annual Report of the Local Government Board for 1877-78.

henceforth viewed as parasitic diseases, being placed side by side with scabies, fungus-foot, and the horrible disease caused by the *trichina spiralis* when introduced into the living body.

It has been mentioned above that, Cohn failed to distinguish *bacillus anthracis* from *bacillus subtilis*. Büchner went further than this: he thought that he had established their convertibility, but both Klein and Koch have published an account of experiments which, in their opinion, upset this idea. I refer to this to call attention to the hypothesis of Von Nägeli as to the convertibility of the different species of micro-organisms generally. This hypothesis has not received the support of Pasteur, who believes that each special process of fermentation or disease has its own special originating micro-organism. While, however, he does not admit their polymorphous character, he himself has called attention to the means of attenuating their activity to such an extent that it could be almost believed that convertibility has taken place. To instance this. He states* that if the most minute drop of blood be taken from a fowl about to die from chicken cholera, and placed in some clear *bouillon de poule* previously sterilised under a temperature of 115°C., and placed under conditions in which neither the outer air nor the vessels employed, can introduce exterior germs, at a temperature of 25° to 35°C., the inoculated liquid grows

* Address on Vaccination in relation to Chicken Cholera and Splenic Fever. By M. Pasteur. *Brit. Med. Journ.*, August 13th, 1881.

turbid and full of tiny micro-organisms. From this cultivated solution, successive solutions can be inoculated to the hundredth or thousandth generated, and if from the last of the series the most minute portion be inoculated under the skin of a previously healthy fowl, the bird will die as surely as though it had been inoculated with the blood taken direct from the fowl which furnished the original source of the poison, and with the same symptoms.

On the other hand, if a considerable interval of time, say a fortnight, a month, three months, or ten months, be observed between the artificial cultivations of the virus, then the virulence of each succeeding product is lessened, notwithstanding the abounding presence of the tiny micro-organisms, (shaped like the figure 8,) until a product is obtained which, when inoculated into a healthy fowl, will make it ill, but will not kill it. "When the fowls have been rendered sufficiently ill by the attenuated virus, which the vital resistance has arrested in its development, they will, when inoculated with virulent virus, suffer no evil effects, or only effects of a passing character." Here, Pasteur says, we evidently touch the principle of vaccination, and he endeavours to show that it is by the agency of atmospheric oxygen that the attenuation of the virus is brought about, for in the absence of oxygen the virulence of successively cultivated solutions is not appreciably impaired. What, then, is the action of the oxygen? Can it be supposed to alter the very function of the germs themselves? or does it oxidise some virulent

chemical secretion or poison which the germs intermediately elaborate or produce? Unless there be an actual process of evolution by which the germ of chicken cholera is morphologically converted into an innocuous form by the agency of oxygen—a supposition which meets with little favour from the highest authorities—the attenuation, it seems to me, must be brought about by a chemical change between oxygen and the real poison, which in that case must be regarded as a chemical substance resulting from the life function of the germ, just as sepsin is elaborated in the process of putrefaction. I am inclined to take this view, and after all there is no distinctive difference between the effects of well-known chemical poisons, such as prussic acid, chloroform, arsenic, strychnine, and the symptoms of diseases of the class of chicken cholera. I am the more inclined to take this view for another reason, which I have set forth in a short critical note of Pasteur's work on this subject.* The interpretation placed by that eminent investigator upon his own observations, necessitates the assumption of the presence in the human body of a number of distinct substances, each forming the proper and distinctive food of a particular parasite, and the further assumption that vaccination in some undetermined way gets rid of such substances, or converts them into products not fit to serve as food. In the inflicted process of vaccination with an attenuated virus, the body be-

* *Chem. News*, vol. lxiii., p. 28.

comes ill, but does not die. It does not die because, if Pasteur be correct, the parasites do not sufficiently multiply. Why do they not so multiply? It cannot be on account of the insufficiency of the pabulum, for when death follows inoculation of an unattenuated virus, it results, so Pasteur says, from the very profusion of the growth of the parasite. The pabulum, which is sufficient to support a given number of parasites, is of necessity able to support a smaller number thereof!

Moreover, there is an utter disregard of quantitative evidence in these various assumptions, for although we are tolerably familiar with the very considerable decompositions effected by parasites, as for example in the processes of putrefaction and alcoholic fermentation, it can scarcely be supposed that even, say in three successive inoculations, the pabulum, afforded by the body of a fowl to the virus of chicken cholera, can be entirely used up; if it be, then its amount must be extremely limited, and its nature is a mystery in itself. What peculiar substance can this be that defies the chemical science of these days?

For my part, I think this is an entirely erroneous line of theory, and if we are to believe in the existence of diseases initiated by germs (and I fail to see how this can be doubted) we must seek for the real poisons that cause death in the secretions of the parasites or in the chemical products to which they can give rise in suitable media. It is easy to understand how oxygen and other chemical substances and

conditions may change purely chemical products, but such change cannot be conceived as occurring in the parasites themselves. It is only a difference of form, as Klebs expresses it, that corresponds to a difference of function, and if we outstep this boundary we must assume the possibility of the transformation of species, an assumption which is, so far, utterly unwarranted and far fetched.

Why should we not be content with the chemical theory, which rests only upon ascertained facts?

The fermentation of sugar into alcohol is carried on by the agency of yeast cells, that is to say, by the life function of a living organism, and one of the chief products of the chemical change thus induced is alcohol,

$$\underset{\text{(Cane-sugar.)}}{C_{12}H_{22}O_{11}} + \underset{\text{(Water.)}}{H_2O} = \underset{\text{(Alcohol.)}}{4C_2H_6O} + \underset{\text{(Carbonic dioxide.)}}{4CO_2}.$$

The fermentation may be carried on until the amount of alcohol thus obtained in solution, is inhibitive to the functions of the yeast, or even destructive to the cells themselves, notwithstanding that strychnine has no effect on the properties of yeast. Thus, the production of alcohol is precisely parallel to the formation of sepsin in putrefaction; and sepsin can, when introduced in sufficient quantity into the bodies of animals, cause death by blood-poisoning. Alcohol itself, in excess, produces poisonous effects, and that it is not more actively poisonous is a mere chemical accident. By the introduction of another ferment into the alcoholic product, in

presence also of air, the alcohol becomes oxidised into acetic acid,

$$C_2H_6O + O_2 = C_2H_4O_2 + H_2O,$$

until it entirely disappears. In like manner, it is easy to understand how other poisonous products of fermentation can be destroyed or converted into innocuous ones by subsequent acts of fermentation or purely chemical change, so that, although such considerations do not afford an apparent explanation of vaccination, they, at least, afford a solution to the process of attenuation with which Pasteur has acquainted us.

There is a further matter which requires attention in connection with this subject, and that is the power of the micro-organisms, or ferments, to produce products varying with the media in which they are living. Thus, Pasteur has shown that the property of exciting alcoholic fermentation is not confined to the cells of yeast, but extends to the elementary organs of plants in general. In brief, the mode of life of micro-organisms enables them to live under many various conditions and in many different media; and corresponding with the difference in chemical composition of the pabulum, there is a difference in the products of their life function, so that sometimes poisonous products may result, and, at others, innocuous products, and according as the one or the other is introduced into the human body, so illness or death may be the consequence, or health may not be impaired.

Before passing on to the study of other subjects, attention should be called to the precise manner in which at least some acts of fermentation are induced. It is thought that fermentation does not represent the immediate result of the presence of micro-organisms, but rather, the chemical changes brought about by a secretion of the micro-organisms which is elaborated in the act of life, after some such manner as saliva is secreted by man. These products are collectively termed zymases, or soluble ferments, and are all derived directly from living organisms: they cause fermentation, however, by purely chemical means. It is in this way that diastase (from malt, vetches, etc.), maltin (malt), emulsin (from sweet and bitter almonds), ptyalin (saliva), pepsin (gastric juice) give rise to the peculiar chemical changes that are so well known in connection with their agency. Thus ptyalin converts the starch of food into sugar; and emulsin converts amygdaline into glucose, oil of bitter almonds, and prussic acid. The soluble ferments are all uncrystallised albumenoid derivatives elaborated by organisms, coagulable by heat and precipitable by alcohol. Taken collectively, their chemical function is that of hydration; that is to say, they influence substances just in the same way that vibriones (or a secretion of vibriones) act upon albuminous principles: they, in other words, split up chemical substances by the fixation of the chemical elements of water.

If now it be conceded that micro-organisms cause disease in man by the poisonous action of their

secretions or the chemical products derived from their life actions, then, since these products may vary with the nature of the media in which they are produced, we may expect to find different diseases or modifications of the same disease, induced by one and the same micro-organism acting under different conditions, and this seems to be the case as found in practice. Proceeding further with the argument, it follows that the presence of a particular micro-organism in the body does not necessarily imply the presence of a specific disease, unless it be a secretion of the germ that causes disease; if, however, the secretion is to be regarded as a mere preliminary, then the specific disease will only arise when the conditions surrounding the life of the micro-organism are of a definite character, and adapted to the production of poisonous products by the chemical action of the secretion in question. After all, it is not improbable that the comma-shaped bacillus observed by Dr. Lewis in the mouths of healthy persons, is identical with the micro-organism to which Koch attributes the propagation of cholera.

Much that is known regarding the etiology of some contagious diseases is against the doctrine of a germ theory. If the germ theory were universally true, then we might expect to meet with large numbers of isolated cases of small-pox and other diseases having little or no connection, since the germs, supposed to constitute the causes, are ubiquitous. But, as a matter of fact, observation seems to indicate that the infectants giving rise to any set of cases are

derived from previous cases, and these again seem traceable to more anterior ones.*

Another study which has some bearing upon our subject is that of the distribution of disease. It is not possible to enter into any detailed consideration of it † here, but it may be laid down as a general proposition, fairly well established by Mr. Haviland, that disease has a geography. He finds that certain districts are store-beds of particular infections, and he is able to trace a connection between such states and local conditions. Thus Cheshire and Lancashire show the greatest death-rate of all the counties in England and Wales, from scarlet fever: "in them scarlet fever seems ever to be stored, ready at a moment's notice to be carried far and near." Then again, the Thames runs through a vast cancer-field; and there does not exist an important river in England or Wales, subject to seasonal floodings, that does not flow through high mortality districts.

These and similar facts brought forward by Mr. Haviland demonstrate that places exist where the local conditions are such as either originate or favour certain specific diseases. These conditions are no doubt very multifarious, and partly concern climatic influences, geological particulars, water supply,

* See "Typhoid Fever, its Cause and Extent in Melbourne." By William Thomson, F.R.C.S. On p. 325 he writes: "True parasites never forsake a host while it lives. Fever germs mature, multiply, and cease. This is a radically important difference."

† See a paper by Alfred Haviland, M.R.C.S., Ed., *Journal of Society of Arts*, vol. xxvii., p. 157; also his work on the Geography of Heart Disease, Cancer and Phthisis. Smith, Elder, & Co.

and so forth. Nevertheless, if the specific fevers were due to ubiquitous germs, then these germs should, of themselves, be able to institute disease pretty uniformly; but we see that this is in opposition to the observed facts.

There is another theory of disease, to obtain a proper understanding of which, it will be necessary, first of all, to explain a few fundamental facts taught by physiological science.

Microscopical examination of the structures and tissues of the living body reveals the presence of a matter termed by physiologists "protoplasm," or "bioplasm;" and it has been ascertained that all forms of animal and vegetable life are derived in the beginning from this substance. It is a living, moving, and growing transparent matter, which exists in every part of the body, and it has the power of taking up or assimilating lifeless material, —pabulum,—which it changes in such a way that its elements lose their inorganic nature, become organised, and form part of the living bioplasm. In other words, bioplasm feeds upon dead matter, and thereby grows, increasing its mass. As this operation proceeds, the mass of bioplasm divides and subdivides into multitudes of smaller parts, and each of these parts gradually assumes a definite form or structure.

It is in this way that at the birth of an animal, the different organs and parts of the fully developed body are formed; and while life lasts, every organ and part is sustained by the formation of new material by the same process. The blood conveys the nour

ishment, from which the bioplasm resident throughout the organism appropriates the proper elements, and converts them into matter like itself, and this afterwards assumes structural form; the newly organised tissue is attached to the parent tissue, replacing that which is destroyed by the act of life. That is to say, in life, the tissues are worn down or away, being resolved into products which are removed in the breath, sweat, urine, and fæces. Every thought and act wears out, in this manner, some part of the living body, which is repaired in the manner above set forth.

This grand fact, although long known in principle, has been largely proved in detail by the researches of Lionel Beale.* He has shown that, bioplasm, occurring in every part of the living body, is germinal matter possessed of a power of selection of elements from the pabulum supplied to it, by which it converts dead or lifeless matter into living matter. By the specific changes which happen in bioplasm at certain stages, tissue results, and hair, skin, bone, nerve, and muscle are produced.

Thus we see that every different part of the body has its own bioplasm, by the growth, division, and change of which, so many different types of matter and the secretions are formed. All this is certain, and it is true, not only of animal, but also vegetable life.

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* "Bioplasm," etc. By Lionel S. Beale, M.B., F.R.S. J. & A. Churchill, 1872.

So long as normal changes go on, the life of the animal or vegetable is normal, and the products of the change in the bioplasm are physiological in nature. But if the senormal changes be influenced extraneously, then other products—departures from the normal type—are formed, and these are pathological in nature.

Such ideas as these, although not so clearly perceived, have existed for ages in the minds of thinking men, and Dr. Drysdale has directed attention to the fact* that, "in Fletcher's Pathology it is laid down more particularly that the exciting cause of all contagious diseases consists of diseased secretions thrown off by animals affected with the same disease; while miasms, or malarious poisons, consist in diseased secretions thrown off by vegetables in a state of disease." This amounts in substance to what has just been stated regarding the normal and abnormal changes of bioplasm, and furnishes us with a theory of contagious disease at once simple, natural, and not absolutely at variance with the so called germ-theory as already described.

Mucus and saliva, like all other substances formed in the body, are derived from bioplasm, and so also is the poison secreted by rattle-snakes; and yet the latter substance is poisonous to man. The precise manner of its poisonous action is not known, but it may be supposed that, containing, of course, as it does, its own bioplastic particles, these are enabled

* See p. 33 of his afore cited Essay.

so to influence the development of bioplasm in the affected part, that a departure from the ordinary changes is effected, and the result is death. It is not, however, by such obvious outside influences alone that the normal secretions of the body are influenced. They are liable to be perverted or diseased by a great number of causes, some of which may be even of a mental origin, and thus the body itself becomes irritated and diseased. It is, then, surely natural to believe that, if this can take place in the body of one individual, the vitiated secretions which are thrown off from the body are also competent to graft themselves upon or in the bodies of others, and similarly influence them.

To perceive all this clearly, it must be borne in mind that just as nerve and muscle grow from bioplasm, so also do the secretions generally; indeed, all living or growing matter necessarily depends upon bioplasm; hence, just as mucus, when examined under the microscope, reveals the presence of bioplasts (the particles of bioplasm), so also do diseased secretions similarly exhibit such particles. If, now, such vitiated thrown-off particles come into contact with another person, they have the power, by virtue of the bioplasm which is contained in them, of grafting themselves in or upon the body, and thus disease is communicated. This is the theory of Dr. Lionel Beale.*

* See Beale's work on "Disease Germs: and on the Treatment of Diseases caused by them." Also Dr. Ross's work on the "Graft Theory of Disease."

Now as bioplasm, whether normal or diseased, may also be called germinal matter, since it is literally living matter, it may be allowable to speak of disease germs; but if this be done, it should also be pointed out that by this expression it is not intended to imply parasitic organisms of definite morphological characters. Such organisms are not comparable with bioplasm, for they themselves grow and develop by means of their own bioplasm, and hence they are only comparable in this sense with other organisms possessing structure, such as man. Bioplasm has no structure.

Since, however, the public at large have been misguided in the use of the word "germs," it is better to speak of the "graft theory of disease."

In the face of what has just been described, it is particularly interesting to turn back to the views maintained by Liebig against those other scientific men of his day who advocated the parasitic theory. Liebig admitted the existence of vital force in a primary sense, and he maintained that (which to-day cannot be disputed) the life of an organism follows a determinated course, which results in a definite form and composition of the parts. While this process continues it is normal, and the result is health. If opposed by extraneous influences, the vital power of the organism resists them, or succumbs to them, according as to which is the more powerful process. Should the foreign power prevail, then the normal performance of function is interfered with, and the results are pathological.

It is seen that Liebig's teaching also establishes the individual power to resist disease, some persons being more susceptible than others, and thus succumbing more easily to its attacks. This individuality depends upon a great variety of conditions affecting personal history and surroundings.

In illustration of the graft theory of disease it will be instructive to mention a few facts.

In health, the clear, colourless fluid called mucus is a product of the transformation of the bioplasm of the mucous membranes; but floating about in it there are particles of living bioplasm which have been derived by division from the resident masses. Now if there be an excessive supply of nutriment, or, if from some cause, over-stimulation of the activity of the resident bioplasm results, then instead of mucus being produced, an imperfectly elaborated, or degenerated, product is formed, viz., pus. In the same way as pus may take the place of mucus, so other parts of the organism may be similarly degraded, owing to the interference and influence of an extraneous power, and diseased products thereby result.

While health lasts, as already stated, every different tissue and part of the body grows from its own specific bioplasm; but pus is a fluid containing a common degraded form of bioplasm or germinal matter, which goes on living and reproducing itself, but which cannot form tissue. It is common, in the sense that every kind of bioplasm may, by similar degradation, give rise to it.

Here, we have a remarkable instance of the conversion of a living matter, which ordinarily would go to make tissue of some kind, into another living matter which has no power of forming tissue, but only the power to reproduce itself and to produce a fluid (pus), which is liable in itself to be both acrid and irritating, and which, when further changed as by the putrefactive process, can and does produce even fatal results.

Similarly, the specific contagia of the fevers and other contagious diseases may possibly be degraded forms of bioplasm, which exhibit great powers of resistance (owing to their vital nature); they may be preserved in the moist or partially dry state, within certain limits, and when imperfectly desiccated may be carried hither and thither by air or in water.

Without overstraining the analogy between ordinary infective processes, and the infective process of a cancerous growth, Dr. Creighton's investigations * of this last-named disease are of extreme interest, if viewed side by side with the graft theory.

Dr. Creighton has shown that cancerous diseases are characterised by the chronic self-propagative nature which they exhibit. When the elements of the originally diseased parts are carried by lymph or blood-streams to other parts, these latter are impregnated, and the tumour grows out of the original textural type. This result is not due to any specific organisms resident in the parent tumour, but

* Reports of the Medical Officer of the Privy Council. New series, No. 3, 1874, and No. 8, 1876.

rather to a ferment-like power of the transported elements which induces previously healthy parts to grow after the manner of the infectant.

These observations are vastly important, because it seems that in such studies the actual process of infection can be watched; and, so far as at present determined, the process strictly accords with what might be expected to take place assuming that the secondary infection is due to the influence of degraded bioplasts derived from the primary growth.

Enough has been said to show the grounds upon which the graft theory of disease is founded; and it may be taken as well established that, just as one kind of plant or tree may be grafted on to another, by virtue of the living matter contained in the graft, so also graft bioplasts exist which are capable of attaching themselves to, and growing upon, the previously healthy body, thereby producing a departure from the normal life history, or in other words, instituting disease.

The phenomena of infective processes are thus well explained; and granted that parasitic germs can and do produce disease also, it may possibly be that this is owing to their secretions rather than to themselves as living bodies preying upon the host. The bioplasm of the parasites may possibly create the disease, or the parasites may be the bearers of degraded bioplasm obtained elsewhere.

Of course it cannot be denied that evidence of an extensive and comprehensive nature is wanted; and until more facts are ascertained by strictly-conducted

and accurate investigations and observations, we shall not make any material advance in our knowledge of the nature of contagious diseases.

Writing of those diseases which now never arise except from infection, Dr. Drysdale says "their origin is hidden in the night of time;" and "although we may circumscribe the area of their operation, yet we can never hope that good food, virtue, drainage, and ventilation will extinguish them altogether, as long as man is a social animal."

Again, writing of another class of infectious diseases, —such as the catarrh and erysipelas group,—he says that as long as these "arise from the operation of mere common non-specific causes, if by any chance they were swept clean out of the land, they would infallibly reappear, so long as poverty, dirt, overcrowding, famine, war, vice, etc., afflict the human race."

It has then been shown that there are:—

1. Diseases which are due directly or indirectly to parasites (including micro-organisms).

2. Contagious diseases which depend perhaps upon graft-germs (degraded forms of bioplasm).

3. Diseases which are due to mere chemical products, as is probably the case with the blood poisoning produced by sepsin.

Finally, it is seen that all these diseases originate from matters of an animal or vegetable origin which may be directly derived from organisms by certain processes of change induced by degraded bioplasm or by microphytes (as in putrefaction).

And now having reviewed the various theories of disease, and the facts upon which they are based, to what conclusion are we impelled as regards the practical prevention of epidemics? The only conclusion points to the necessity of observing cleanliness of the body as of paramount importance with the health of the mind, and of securing pure air, water, and food as also absolutely essential to sanitation.

While, however, the hope of ever extinguishing the contagious diseases is built upon a poor foundation, it must still be borne in mind that there exists a terribly large amount of actually preventible disease.

To use the words of Professor Corfield:* "People who are living in the midst of general unsanitary conditions are in a worse plight than people living in the crater of an extinct volcano; for not only may any one of the severest epidemic diseases break out among them at any time, but they are continually sacrificing unnecessary victims to the demon filth."

It is beyond doubt, that were the evacuations of typhoid-fever patients destroyed or properly treated in good time, there would be an end to, at least, a vast majority of the 100,000 cases that occur every year. Then, again, all the fever that owes its origin to well-pollution by drainage from the farmyard and its abominable heaps, is likewise preventible. Further, all diseases due to the putrefaction and decay of animal and vegetable matters are mere expressions of

* Address to the Sanitary Congress at Croydon, 1879.

insanitary conditions, and could be wholly avoided. While as regards such diseases as small-pox, scarlet fever, and the other members of the more contagious class of diseases, it is in human power to prevent also the majority of cases by a judicious circumscription of the area of disease in the application of strictly scientific methods.

In another chapter an endeavour will be made to ascertain how far the use of antiseptics and disinfectants assists in the accomplishment of such a desirable end as the prevention of epidemics.

CHAPTER VIII.

ANTISEPTICS AND ANTISEPTIC SURGERY; DISINFECTANTS AND DISINFECTION.

THE scientific use of chemical reagents for the purpose of preventing infectious diseases is necessarily governed and controlled by what is known respecting the causes of these diseases.

In the last chapter it has been shown that, undoubtedly certain infectious diseases are primarily caused or originated by living micro-organisms. Respecting, however, the more important contagious diseases, including small pox, scarlet fever, typhoid fever, syphilis, etc., no absolute proof has been forthcoming, and in considering the means to be employed for their prevention, we have to depend upon general considerations and experience.

For the sake of argument, let it be conceded that all infectious diseases are originated by micro-organisms which prey upon the human body. How, then, are we to prevent their spread? That is the question which is involved in the scientific use of disinfectants. Fantastical definitions of the words antiseptic, disinfectant, germicide, and so on, merit

no consideration:* we have simply to deal with the prevention of diseases which we will assume to have a common originating cause in micro-organisms † (germs).

This being assumed, the next point to consider is, how these micro-organisms produce disease and death; and in answer to this question scientific investigation of a practical kind has not, so far, provided an unequivocal reply.

* Equally unworthy of attention are the attempts often made to cast discredit upon some particular disinfectant by unscientific arguments, or by experiments dealing with some one point of interest having little or no connection with the heart of the subject. I have in mind, at the moment, certain criticisms made by Mr. A. Wynter Blyth* on the exhibits of disinfectants at the Health Exhibition. These criticisms consist of very ordinary observations, to which, however, as concerns some of the exhibits, a bias is given by a reference to certain experiments made upon the spores of anthrax. In these experiments no substance was found to wholly arrest the growth of these particular spores, which are extremely resistant in character. He, however, mentions a certain preparation, which in his hands delayed their growth, but because the spores subsequently developed after removal from the disinfectant, Mr. Blyth takes occasion to say he would not rely upon this disinfectant in serious cases. Such a criticism of any one disinfectant is grossly unfair, firstly, because the author produces no proof that the spores he operated upon were capable of producing anthrax; secondly, because he did not investigate the properties of the spores after treatment with, as also in the presence of, the disinfectant; thirdly, because anthrax is here made to serve as illustration of all infectious diseases; and lastly, because it utterly ignores rebutting evidence contributed by many other scientific men.

† Consult the pamphlet by Dr. Charles Cameron, M.P., on Microbes in Fermentation, Putrefaction, and Disease. Baillière & Co., London.

* *Medical Times*, October 11th, 1884, and my reply in same paper November 1st, 1884.

In investigating the relationships of micro-organisms and disease, with the object of proving that a particular infectious disease is due to a particular micro-organism, Koch and Klein have pointed out* that the following conditions must be observed :—

1. It is absolutely necessary that the micro-organism be found present either in the blood or the diseased tissues.

2. It must be possible to take the micro-organism from its nidus and cultivate it artificially in some suitable medium, to successive generations, care being taken to exclude the introduction of all other micro-organisms. The object of this proceeding is to free the particular micro-organism from every kind of matter derived from the animal body which furnished the microbe originally.

3. It must be shown that the cultivated microbe is capable of producing the particular disease by inoculation of the healthy body of an animal.

4. The micro-organism must be found associated with the disease in the body of the animal thus secondarily infected.

It will, however, be seen, at once, that it is absolutely impossible to dissociate any particular micro-organism from its own secretions and life products, for successful artificial cultivation implies the presence with the microbe of a suitable medium, in which it lives with ease, and multiplies. So that, after all, such investigations can only indicate micro-organisms

* *Die Milzbrand-Impfung.* Cassel und Berlin, 1883 (Koch). *The Practitioner*, March, 1884, p. 171 (Klein).

to be the first cause of disease, but they are not adapted to the elucidation of the real direct cause. It is not even sufficient to separate the solid from the fluid parts of cultivation liquids, and to prove that the sedimentary or solid parts are infective, while the fluid parts are inactive. This is proved by the experiments of Panum and Burdon Sanderson, in which it was demonstrated that in certain sterilised cultivation-mixtures it was the solid particulate parts that induced septicæmia in animals, and that these particles consisted of a chemical substance (sepsin) elaborated by micro-organisms. Further, filtration through clay, or gypsum, removes sepsin from cultivation-mixtures, and allows an innocuous liquid to pass through the filter: processes, then, of sedimentation and filtration cannot be resorted to with the assurance that they remove only the particulated micro-organisms. Any test which may be applied to such filtrates must be of an imperfect character. Rather, means must be found of sterilising cultivation-mixtures, so that, after there is obtained an assurance of the absence of living micro-organisms, tests may be made with the isolated particles to ascertain if they can induce disease in animals. The difficulty in applying such tests would be to make sure that the means adopted for sterilisation do not affect or alter the chemical nature of any substances that may have been elaborated by the micro-organisms in the cultivation-mixture.

Thus, after all, we have, at present, to depend very much upon the scientific use of the imagination in

drawing up measures for the prevention and cure of infectious diseases.

It would be unscientific to suppose that the mere presence of micro-organisms in the body causes death; it must be conceded that disease and death are due to certain effects of their presence, and not to the mere mechanical lodgment of living matter in the wrong place. Irritation and local disturbances alone could arise from such mere lodgment. To ascertain their effects we must make ourselves acquainted with their life-history; but at present we know little more than that, in common with all living organisms, they require food, and reproduce their kind. These acts of life are attended with the production of excretions and secretions, and all recorded information concerning the chemistry of the living body would point to some product (being either a secretion or a constituent of the excreta) as constituting the direct cause of death to the higher organism preyed upon by these micro-organisms.*

Indeed, practical investigation has afforded what may be regarded as a proof of this statement. The fermentation of sugar and the resulting production of alcohol is not induced by the mere presence of yeast cells in the solution, but it is the consequence of a chemical change imparted to the sugar by a secretion of the yeast cells; this secretion is a product of the life-action of the yeast cells.

* Compare "Infectious Diseases in the Army," by Professor Rudolph Virchow. Translated from the German by John James, M.B. London, F.R.C.S. (H. K. Lewis).

Again, blood-poisoning which results from the introduction of putrilage into the system, is not brought about by micro-organisms in any direct sense, but only indirectly. In a suitable medium these organisms live and flourish, and elaborate a purely chemical poison, termed sepsin. This substance may be a secretion, or it may be a chemical product otherwise derived from the albumin upon which the micro-organisms depend for food.

If this view be correct,—and to my way of thinking no other view is tenable,—then practical disinfection does not demand the destruction of the microbes themselves, but only the prevention of the production of certain poisons which they excrete, secrete, or elaborate concurrently with their development in a suitable medium. To use the words of Professor Virchow, "These secreted poisons are conceivably isolable from the micro-organisms which have hatched them; their activity is not tied to the presence of the fungus any more than the fungus itself is of a poisonous nature."

I am convinced that unaided morphological studies of microbes will not lead to any final conclusions respecting infectious diseases, but that chemical studies supplemented by physiological experiments will alone do this.

In a word, the method of investigation originated by Panum and continued by Burdon Sanderson should be prosecuted in connection with the microbes which are associated with disease generally. This method has for its object the separation of the

microbes from the chemical products to which they give rise under specified circumstances, with the view of ascertaining the consequences of inoculating animals with the poisons that they will probably be found to produce.

Experiments of the kind carried on by Mr. A. Wynter Blyth, and referred to above, are comparatively of no value, because there is no key of interpretation to the results.

Many investigators are of opinion that each infectious disease is originated (indirectly of course) by one particular microbe, but morphological investigations can scarcely be said to have given an adequate proof of this contention, and in any case it would be hopeless to attempt the universal extermination of micro-organisms which originate disease, for they are apparently ubiquitous, and constitute an order in creation. Collectively, indeed, they constitute a most useful and necessary order in creation, for by their agency, or that of some of them, putrescible organic matter at large, is converted by hydration and oxidation into innocuous and useful, nay, essential ultimate products. But while it is injurious to have the micro-organisms of putrefaction at work in our houses, it is even more prejudicial to health to have them or others at work in or upon our bodies. If they effect a residence in or upon the human body, and the conditions necessary for their reproduction be present, disease results, and death may supervene.

What chemical means and agents, then, are to be employed for the prevention of such diseases?

They are both general and special.

The general means include cleanliness; the studied exclusion of putrescible matters and processes in and around human dwellings, and a due provision of pure air and pure water. Every medical practitioner and every sanitarian, irrespective of favourite theories as to the causation of preventible disease, is assured of the help which filth and insanitary surroundings give to contagious illnesses. That being so, every chemical reagent which admits of being usefully employed in ensuring chemical purity is a disinfectant in the best sense of the word.

Liebig pointed out that miasmatic diseases are endemic in places where the decomposition of organic matter is constantly taking place, as in marshy districts, and that these diseases become almost surely epidemic when a marshy area is dried up by continued heat.

Besides this, it is known, with certainty, that some animal substances, in a state of decomposition, can excite a diseased action in the bodies of previously healthy persons. This is often experienced in anatomical theatres; the slightest wounds made with instruments which have been used in dissecting putrefied bodies not rarely lead to dangerous and even fatal results. In such cases, poisonous matter is communicated to the blood in the living body, and, even in such infinitesimal amounts, is capable of producing the most terrible results.

Mr. Haviland, who has made a special study of the geographical distribution of disease, writes as

follows * :—"Typhoid fever has no reason for existing at all, but whilst the porous soils of the sites of our villages are being polluted as they are, we must expect well-contamination and its sequel—fever. One great source of well-pollution, which I have known to be the origin of much fever, is the farmyard and its manure heaps. At present, the rural sanitary authorities are generally composed of farmers and others who cannot, or will not, see anything wrong in their barbarous muck heaps. The medical officer of health sees their effect daily. The effect of vegetable decomposition on the human system is varied, but marked. Let us take first the decomposition which produces ague and other forms of fever, as witnessed in the fen lands, the pontine marshes, and in other swampy grounds. Or remember the peculiar fever that is the result of living near the localities where flax is steeped and decomposed, or where indigo is allowed to ferment. Then, again, we must not forget that during the American civil war, some few years ago, a form of fever arose, simulating measles, which was traced to the decomposition of the straw on which the soldiers were bedded." †

Attention has already been directed to the peculiar infectant which is contained in putrilage, and which Burdon Sanderson has shown to be of a particulate non-living nature. It is a most virulent blood-poison, and must, from the method of its production, inevit-

* See his paper previously quoted on p. 168.

† See also Professor Virchow's pamphlet previously referred to. It is full of most valuable and precise information on this subject.

ably attend as a product of the putrefaction of flesh wherever this may occur. This being the case, it is most probable that its formation also results from the putrefaction of other animal and vegetable matters containing albumin, since its production from flesh is traceable to the same chemical principle. Sepsin, as this poisonous matter is termed, is a mere chemical product of change capable of exerting a physiological effect in the same manner as hundreds of other chemical substances exhibit peculiar physiological effects. Thus, the inhalation of chloroform produces insensibility to pain, and if taken in excess, results in death. Similarly, if a septic poison be received into the system, it will produce effects which, when recognised, are expressed as fever, and from which death may result.

It may also be borne in mind that many years ago Dr. Semmelweis established the fact, that a number of deaths occurred in a lying-in hospital at Vienna from the conveyance of putrescent matters to the genitals of the patients in an extraordinary manner. The physicians in attendance on the women were largely employed in dissecting, and it was known that these same operators would often leave the dissecting-room to examine women in labour, and thus introduce on their hands the poisonous matter which led in so many cases to puerperal fever, and finally to death.*

It is true that the precise connection of all this with infectiveness is not quite so clear as might be

* See Appendix to Liebig's "Letters on Chemistry," p. 530. This instance is by no means singular.

wished; but we are left in no kind of doubt that at least many, if not all, infectious diseases have their origin in putrefactive and allied processes, and that sepsin is to be regarded as the type of an infectant.

It may, indeed, be taken for granted that the whole experience of the world in all ages goes to show that much preventible disease originates in the putrefaction of animal and vegetable matter going on in the midst of human habitations.

Hence, in sanitary practice we aim at preventing putrefaction under given conditions, and the agents employed to prevent such processes are termed antiseptics. Indeed, an antiseptic may be defined as a substance which, when properly applied, prevents the formation of septic poisons in its vicinity. Such substances are also not rarely termed disinfectants, and indeed it seems clear that if putrefactive change gives rise to infection, then agents which will either prevent or arrest this process may be fairly termed disinfectants.

Dr. Gamgee,* writing on this subject, says, "I am now convinced that every good antiseptic is really a destroyer of disease germs: an arrest of development is ensured."

If a beefsteak be placed in contact with air and water and allowed to putrefy, the resulting product constitutes a most virulent fever-producing product; but if we place with the beefsteak a certain quantity of antiseptic material, the putrefaction does not occur, and the poison is not formed. This is clear, and it is

* *Chem. News*, January 27th, 1871.

certain. Moreover, it is probable and almost certain that the poisonous matter, even if it be allowed to form, may be afterwards destroyed by certain other chemical substances which have the power of oxidising and burning it up, just as all the organic matter in nature is oxidised and burnt up under ordinary atmospheric influences.

The special means for the prevention of infectious disease are of the same order, but resolve themselves into the use of antiseptics or disinfectants more locally, and, if possible, at the seat of disease, with the object of avoiding the results that follow from the unimpeded development in the human body of the micro-organisms upon which disease depends.

Unfortunately, these microbes, or some of them, exhibit very tenacious powers of resistance (a feature which received some special attention in the last chapter), and some of their spores, at least, survive the application of parasiticides, even if employed of sufficient strength to poison the patient (host). The fully developed micro-organisms are more amenable, however, to such reagents than are the spores or immature germs to which they give rise, and by which they are reproduced to successive generations.

We must include, then, among disinfectants those substances which destroy the life of microbes (irrespective of kind; for whether any one parasiticidal agent is fatal to all kinds of micro-organisms is yet unascertained). Among such substances are peroxide of hydrogen and permanganate of potassium (which are at least fatal to anærobies generally), and thymol,

iodoform, corrosive sublimate, chloral and phenol, each of which acts destructively to certain classes of micro-organisms, and particularly ærobies.

The application of such chemical reagents to putrid mixtures results in the cessation of putrefaction, and the reason why such application remains efficacious is either that the presence of the chemicals prevents the development of further spores into the mature state, or else that they kill each organism as it is developed. They act in the same way towards the microbes that initiate diseases.

The precise mode of action of disinfectants must necessarily be various in character. It is possible, for instance, that peroxide of hydrogen acts as a direct poison to anærobic germs of the putrefactive type. It may asphyxiate microbes, that is to say, by its active oxygen, just in a similar way to that in which carbolic acid acts as a direct poison to man.* Preparations, such as pyrogallic acid, may act in the directly opposite manner, viz., that of absorbing the oxygen necessary for the life of some microbes. Other chemical reagents, such as tannin, may render the medium in which the micro-organisms exist, unfit for their further sustenance, by entering into combination with the albumin upon which they may have hitherto depended for food, thus converting it into a substance which they cannot decompose. In this way they may be starved out of existence. Or yet again, just as a man may

* Phenol does not necessarily act as a poison to disease germs.

be anæsthesiated by chloroform or ether, so also may be micro-organisms. Thus, Claude Bernard has shown that the sensitive plant loses its irritability when placed in contact with the vapour of ether, but regains it if the ether be removed. If not removed the plant dies. Again, if the yeast plant (which is a type of disease-organisms) be placed in an etherised sugar solution, it will no longer act as a ferment, and ceases to be reproduced until and unless the ether be removed. If not removed, the cells succumb to the ether and finally die.

It will be evident, then, that there are more ways of destroying disease germs or microbes than that of the doubtful process of direct attack. They can be starved out of existence, or they may be anæsthesiated, or the general conditions surrounding their existence may be so influenced that further life becomes impossible. Collectively, all chemical agents, which lead by their employment to the death of the micro-organisms which breed disease, are disinfectants in the only true sense. It is also perfectly conceivable that many chemical reagents may exercise such an influence over microbic life, that without destroying it, its functions may be so diverted as to be carried on without danger to health in the body of human beings. That is to say, instead of poisonous products, innocuous ones may be formed by their life functions. Heat is not a disinfectant, but a disinfecting agency.

Prevention is better than cure, for if the microbes of disease obtain access to the muscles, or the blood,

or the bones, then the host may first succumb to the chemical reagents that are used with the view of destroying the parasites alone. The use of disinfectants for internal administration greatly limits their available number, and this is a subject that has received far too little attention. The only direction in which it can be said to have been tried at all, is in connection with the treatment of throat and lung complaints by a process of inhalation. There are many who think with Drysdale, that probably the best means of protecting persons against such diseases as small-pox, will be found in the extended art of vaccination, and that the most efficient treatment of other diseases, such as ophthalmia, is the practice of inoculation. Unfortunately, we are without any accurate information as to the manner in which these practices confer protection or immunity.

In the use of disinfectants for the prevention of parasitic diseases (in contradistinction to their cure), regard must be had also to their general characters and their influence on health.

Dr. R. Angus Smith has said tersely enough, "We live in air, and the air flows continually into our blood; no wonder, then, that we are influenced by climate, which means the condition of the air." *

Carbolic acid, for example, is a deoxidising agent which, when added to the air, vitiates it both by diminishing the available oxygen, and by its mere

* "Air and Rain," p. 3.

poisonous presence. Similarly, sulphurous anhydride uses up useful and life-giving oxygen by becoming oxidised into sulphuric acid.

For universal use a disinfectant must have the following characters * :—

"Firstly, it should not be dangerous if by any chance it be taken internally, and we know that in the case of carbolic acid, for instance, fatal accidents from its use are of constant occurrence. Secondly, it should not be destructive of any substances to which it is applied, as such a quality would necessarily limit its action, and it could not be used, as noted above, to saturate sheets and cut off infection. Thirdly, it ought not to be offensive, for, even postulating the efficacy of an evil-smelling disinfectant, it is never likely to become popular, and it is to the general, we might almost say the universal, use of disinfectants that we must look for any permanent mitigation of the evil exhalations that so often pollute the atmosphere, and which almost invariably carry with them the germs of disease. Many disinfectants offered to the public fulfil one or two of these requirements; while others, though effectual enough, contain recognisable elements of danger. Only one or two may be used with confidence wherever a disinfectant is needed, always remembering that as the nation is reputed happiest which has no history, so that individual may be esteemed the most fortunate who manages so to

* *Standard*, September 11th, 1878.

purify his premises and order his household as to have no need to use a disinfectant at all."

The only disinfectant which, while possessing all these characters, also acts upon anærobic and ærobic forms of life alike, of which I have knowledge, is that known as "Sanitas," for the existence of which I am proud to take credit.

The following is a list of some of the better-known antiseptic and disinfectant reagents :—

Sanitas (containing Peroxides, Thymol, soluble Camphor, etc.).
Ozone.
Peroxide of Hydrogen.
Permanganates of Potassium, Sodium, and Calcium.
Chromic Acid.
Carbolic Acid (Phenol).
Perchloride of Mercury (Corrosive Sublimate).
Eucalyptus Oil.
Thymol.
Chloride of Zinc.
Sulphate of Zinc.
Sulphurous Anhydride.
Iodoform.
Subnitrate of Bismuth.
Chloride of Lime (Bleaching Powder.)
Chlorine (Gas).
Sulphate of Iron.
Sulphate of Copper.
Lime.
Perchloride of Iron.
Iodine.
Creasote.

Each of these substances acts in its own special chemical manner, but, broadly speaking, those disinfectants which are incidentally oxidants also, are to be preferred for two well-defined reasons : firstly, because they are antagonistic to the whole class of anærobic germs ; and secondly, because they have the power of chemically altering by oxidation the products of the life action of germs in general, thus assuring the destruction of the organic poisons contained therein.

The use of antiseptics in the practice of surgery has now become almost general, thanks to the advocacy, in particular, of Sir Joseph Lister. A large part of the total mortality experienced in surgery was due to blood poisoning, which resulted from the absorption into the system of decomposed secretions from wounds. The decomposition in question is common putrefaction initiated in the secretions by air-borne micro-organisms, and the practice of using antiseptics for preventing putrefaction in wounds is sometimes termed "antisepsis." Some writers view this prevention of the development of bacteria in wounds as something quite distinct from disinfection proper, by which expression they seek to represent the annihilation of micro-organisms; but this distinction is, in my opinion, altogether too nice and unreal. At least, it matters not at all whether we speak of disinfecting wounds or keeping them in an antiseptic condition, so long as the object of the process, viz., a healthy state, be attained and maintained. So also, through the whole range of disinfection the same argument applies, and we may freely disregard the fine-drawn distinctions, and illusory differences, that too often find expression, and are apparently employed to cause alarm by many writers on the subject. To use Sir Joseph Lister's own words,* "We do not require any scientific theory in order to believe in antiseptic treatment; all you have to believe is that there are such things as

* *Lancet*, November 3rd, 1883, p. 765.

putrefaction and other septic agencies; that our wounds are liable to these; that they are very pernicious; that these things come from without; and that we have the means of preventing them by various chemical agencies."

A wound which is attacked by atmospheric germs becomes infected; any chemical reagent which, by its presence, prevents this infection is an antiseptic, and if any such substance removes existing infection, as proved by the restoration of the wound to a healthful condition by its use, then that antiseptic is also a disinfectant, and it is downright nonsense to combat the statement.

The practice of antiseptic surgery depends then upon the employment of measures (notably cleanliness and filtration of air) for keeping air-borne germs out of wounds, and for preventing their development in the wounds, if introduced, by the use of antiseptics.

There is one great danger in the practice of antiseptic surgery, although it is by no means essential to it, and that is, the possibility of poisoning patients by the absorption of noxious antiseptics. Many lives have been lost by the employment of carbolic acid,* but now that there are better antiseptics known to science, such as "Sanitas," which is non-poisonous, the necessity for using poisonous antiseptics no longer exists, and their employment is to be condemned in the strongest possible terms since it unnecessarily

* Iodoform also exhibits very powerful toxic effects.

exposes suffering humanity to danger of life and limb from their toxic effects.

It is a mistake often made by surgeons to imagine that in the proper practice of antiseptic surgery they require to use the most corrosive and actively poisonous substances they can command. It should be remembered that the process of putrefaction does not attack living tissue, but only dead matter, and the surgeon should as carefully remove (by cleansing operations) dead tissue, thus minimising the chances of infection, as he attends to the use of his antiseptics, for it is this dead matter that constitutes the pabulum of disease germs in the case of wounds.

As I think, therefore, disinfection is to be carried on with the object of so influencing the conditions of life of the microbes associated with specific diseases, that they shall cease to produce the poisonous substances constituting the real direct causes; for, in all probability it will be found that the microbes themselves are universally distributed in nature, and that it is idle to think of exterminating them. But although they cannot be exterminated, they can be controlled in relation to disease, just as it can be done in connection with the process of putrefaction as observed in the laboratory. This process, in all probability, amounts to the same thing as disease, with this difference, that it is best known in connection with lifeless matter derived, however, from living sources.

The various ways in which microbes can be

controlled have been already described, and it only remains to indicate the general manner in which disinfection is to be carried on in connection with each particular disease. This will be studied in the next chapter.

CHAPTER IX.

TREATMENT OF THE SICK, AND NOTES ON THE CHIEF INFECTIOUS DISEASES AND DISINFECTION.

PERSONS who are attacked with any infectious disease should be immediately isolated from friends and relations, and the nurse and doctor should alone visit them. The sick room intended for occupation in such cases, should be as near the top of the house as possible, and requires some preparation beforehand. It should be well ventilated, and all superfluous furniture and effects should be first removed. There should be no carpets, or curtain hangings, pictures, books, and unnecessary clothing in the room, which should be provided only with absolutely necessary articles.

It is best to keep a fire in the room, with the view of promoting ventilation, and carrying any infective particles floating about in the air of the room through the fire or up the chimney.

Outside the door of the sick room it is well to hang a sheet, so arranged that before the door is opened it can be restored, so as to make a tolerably perfect screen for intercepting the air that may come from inside the room. This air may be contaminated with

the virus of the disease, and hence it requires disinfection, which is carried out by keeping the sheet moistened with a disinfectant, such as pure sanitas fluid, or a dilute solution of sanitas emulsion, containing about a table-spoonful of the emulsion to a pint of water. A spray-producer may be used for moistening the sheet from time to time, and also for spraying sanitas fluid about the sick air. Nothing is more grateful to the patient than the free use of sanitas in the room: "It has a most pleasant, agreeable smell, and refreshes and purifies the room" (Henry C. Burdett), besides which it keeps the air disinfected.

The ventilation of the room can be well carried out by a plan first suggested by Mr. Hinckes Bird, which consists in raising the lower sash some few inches and placing beneath it a bar of wood, so as to entirely close the space; air can then freely enter the room up between the overlapping sashes without creating a draught.

Personal cleanliness of patients is of the highest importance, and, subject always to the opinion of the doctor in attendance, copious ablution is to be recommended. It is a good plan to keep all water used for such operations in an antiseptic state by the addition of a little sanitas fluid or chloride of zinc, or permanganate of potassium.

Before removing any linen or clothing from a sick room it should be first steeped in a disinfectant solution and then wrung out, and, after removal, instantly boiled with plenty of soap and some disinfectant.

The dresses and clothing worn by attendants should

be as non-porous as possible, cotton stuffs being for this reason much preferable to woollen garments.

Any dry food not eaten by the patient should be burned in the fire in the room, and any liquid food, together with all slops and the excreta, should be mixed with some disinfectant before removal. Sanitas powder or emulsion may be used for this purpose.

It is a good plan also to keep the air and contents of a sick room in an antiseptic condition by the evaporation of a little sanitas oil floating on water, or other reliable antiseptic, from time to time.

Handkerchiefs should not be allowed for use by the patient, but only rags, that can afterwards be burned in the room. The breath of patients should not be inhaled by attendants.

The medical officer of health for the district should be made acquainted immediately with the outbreak of any case of infectious disease.

After recovery of the patient, everything in the sick room that is not valuable and that can be burned, should be destroyed in the fire. All linen should be steeped in some disinfectant solution before removal, and then well boiled with plenty of disinfectant soap.

Clothing and bedding should not be removed until after fumigation of the room, and if then there is an opportunity of getting them disinfected in a heating apparatus such as is employed by many sanitary authorities, so much the better. Before the patient leaves the sick room if possible, and in any case

before he mixes with other members of his family, he should take a bath containing plenty of sanitas fluid, and be washed all over, using disinfectant soap.

Fumigation may be carried out by closing the windows, doors, chimney, and keyholes, and evaporating in the room plenty of sanitas oil. This evaporation can be conducted by the use of an appliance sold under the name of the sanitas fumigator; or failing that, an iron saucepan or kettle may be employed, charged with plenty of water (say one quart) and a small teacup-full of sanitas oil. The saucepan or kettle is to be boiled over a gas lamp, (due precautions being taken against the occurrence of fire), during at least one hour. So long as there is plenty of water in the apparatus there is no fear of an accident from the use of sanitas oil, and, of course, more water can be placed in the vessel when required, as the escape of the sanitas vapour from the room into the house will do no harm, and is not even disagreeable, so that a person may enter the room from time to time to see all is well.

Before conducting the fumigation, any articles of wear or bedding unavoidably left in the room should be spread out as much as possible, or hung on lines so as to freely expose them to the fumes of the disinfectant.

It is best to strip the walls of all paper, and to burn it afterwards, and the ceiling and walls should be limewashed. All furniture, woodwork, and metalwork should be polished with sanitas disinfectant furniture cream, and the floor should be scrubbed

with disinfectant soap, using water containing in each bucket say half a teacup full of sanitas emulsion. Before use, the room should be left, with opened windows, unoccupied for at least a week. In case of death, the body should be well sprayed with sanitas emulsion diluted ten times with water, and burial should take place as early as possible.

Small Pox belongs to the class of eruptive fevers, and is altogether a terrible disease. The incubation takes about fourteen days, after which headache and backache come, and then spots appear on the face and wrists which are sometimes mistaken for signs of measles. In this disease, the scales and powder which brush off the skin are highly infectious. To prevent their general diffusion, which would, if not guarded against, very likely infect other persons, it is advisable to anoint the body of the patient daily with a mixture of sanitas oil (1 part) with olive oil (7 parts), or with a mixture of sanitas oil and vaseline.

According to Weigert, the lymphatics of the skin in the region of the pocks are filled with micrococci; but similar micrococci occur also in the fluid contents of vesicles in the skin produced by non-infective inflammations, and there is as yet no proof of any intimate causal relation between these germs and small pox.

The best protection against small pox is afforded by vaccination in infancy, and it is generally considered advisable to revaccinate children at fifteen years of age in order to ensure perfect protection thereafter.

Scarlet Fever and Scarlatina are names for one

and the same disease. This is also an eruptive fever, the first sign of which is, generally, sore throat, accompanied or quickly succeeded by shivering, headache, heat of skin, and, perhaps, vomiting. On the second or third day the eruption appears on the neck, face, or chest, or on the arms near the elbows. Later on, the breath may become offensive, and an offensive discharge may pass from the nose.

In this disease, the skin requires anointing, as in small pox; indeed the greatest care should be taken to prevent dissemination of the meal-like particles or flakes that may peel off the skin. The oiling of the skin should be commenced almost from the first recognition of the disease, and continued until the cure has been completed. Attention should also be paid to the disinfection of the discharges by means of sanitas powder. After some time, baths taken daily, or on every alternate day, are permitted to the patient, but of course the water should be used warm and in an antiseptic state, and after each bath the skin should be again anointed. In severe cases of fever, the skin may also be sponged with tepid water containing some sanitas fluid.

The throat affection, when present, is best treated by inhalation of the mixed vapour of sanitas oil and water; or the throat may be sprayed several times a day with sanitas fluid, diluted five to ten times with its own volume of water, or a gargle of this mixture may be employed.

Micrococci have been described as occurring in the blood, ulcerations of the throat, and adhering to the

scales of the desquamating epidermis in scarlet fever, but the relation of them to the disease remains to be ascertained.

Typhoid Fever (enteric or gastric fever) begins with a feeling of illness and diarrhœa, and the patient is generally more or less delirious in this disease. It is wholly preventible, inasmuch as it owes its origin to sewage contamination of air, food or drink. It is often accompanied by ulceration of the bowels, which, not unfrequently, results in fatal hæmorrhage.

The eruption consists of a few (sometimes many) scattered rose-coloured spots, which can be felt with the finger, and they occur in successive crops. The contagion is eliminated in the discharges from the bowels, and hence it is of the very highest importance to disinfect these by the addition of plenty of sanitas oil or powder, or some other agent. Similarly, soiled linen must be very carefully disinfected.

Although Klebs and Eberth have described bacilli found in inflamed Peyer's glands, mesenteric glands, spleen, larynx, and lungs of patients who had died from typhoid fever, Klein is of opinion that it is doubtful whether they can be considered as necessarily and ultimately connected with the disease, "seeing they are not constant, and only occur in the mesenteric glands and spleen, *i.e.*, in localities into which an immigration of putrefactive bacilli from the bowels may easily take place." He adds that the bowels in typhoid fever always contain innumerable masses of micrococci in colonies.*

* *Practitioner*, June 1884, p. 410.

Typhus Fever is said to be often indistinguishable from typhoid fever, and until recently it was regarded as the same disease. It is, however, rarely accompanied with diarrhœa, and the rash comes out about the fifth to eighth day of the fever, whereas in typhoid it begins from the seventh to the fourteenth day.

The treatment of both diseases is practically identical, but in typhus great advantage is derived from the employment in the sick room of aerial disinfectants and free ventilation. The use of an antiseptic mouth wash by the patient is also to be recommended.

Cholera, in its origin, is probably related to typhoid fever; that is to say, it is more or less a filth disease, and the contagion is carried with the discharges from the bowels. Intemperance in eating and drinking is supposed to invite the disease, and in times of threatened attack, unripe and over-ripe food, tainted vegetables and fish, etc., are to be specially avoided.

I have already pointed out, in an earlier chapter, that the comma-shaped bacilli, supposed by Koch to cause cholera, have been found by Lewis in the mouths of healthy persons, and Klein has not given his support to Koch's views. Koch found that it was necessary to have the nourishing medium alkaline in character, and that the bacilli are killed by drying.

Diarrhœa is allied to cholera, and in both diseases special attention has to be paid to the disinfection of the discharges.

Diphtheria begins with general depression and sore throat, followed by stiffness of the neck and swelling. In fact, it has been described as a contagious and epidemic sore throat. The poison which causes this disease is supposed to be often carried in sewer gas. In bad cases, the leathery membrane which spreads over the throat, extends to the palate, uvula, nostrils, cheeks, and gums, and is accompanied with much sloughing and fœtor of the breath. Sometimes it is followed by sudden attacks of temporary paralysis.

In this disease, obviously, the mouth and throat, and all discharges therefrom, particularly require disinfection. Local application of disinfectants, such as dilute sanitas fluid (1 : 5), made by means of a spray-producer and the douche are to be advocated; a gargle, of a strong solution of chlorate of potassium, should also be used, and inhalation of the vapour of sanitas oil may be practised with great advantage.*

Several observers have shown that in diphtheria the membranes include micrococci, but as Klein remarks, in his work already referred to, "cultivations and inoculations with pure cultivations of this micrococcus are still wanting."

Measles is ushered in with fits of sneezing, dryness of the skin, and watering of the eyes; and after some days a mulberry-coloured rash breaks out on the forehead, and gradually extends to other parts of the body. In this complaint, patients exhibit a tendency

* See *Brit. Med. Journ.*, July 23rd, 1881.

to contract bronchitis and other lung complaints; hence it is essential to protect them from draughts, and keep the temperature of the room higher than usual. It is also best to keep the room darkened, as the glare of light is painful to the eyes.

It is only the putrid or malignant form of the disease that is eminently dangerous.

All discharges should be disinfected, and general measures of isolation and disinfection are to be taken during the treatment of the disease.

There is at present no proof that this affection is caused by micro-organisms.

Whooping cough commences with the usual signs of fever accompanied with a cough, and often precedes or succeeds measles. The froth which children affected with this complaint spit out, should be collected in some vessel and disinfected. Handkerchiefs which are used for wiping the mouth should also be disinfected before sending to the wash.

Chicken-pox is a mild eruptive disease which is infectious in character. At first there is a slight feverishness, followed by small conical pimples having a white head, which appear on the breast, shoulders, and neck. On the second day, they develop into a form reminding of blisters, and on the following day the fluid which they contain becomes opaque, after which they break up and fall off piece-meal. Probably, the vesicles contain the infectant, and disinfecting measures should be taken accordingly.

Erysipelas appears somewhat suddenly, and is

generally preceded and accompanied by signs of fever; the affected skin is red, hot, and tender, and is often blistered. It is frequently associated with sore throat, and generally appears on the head or face, which sometimes swell enormously. It is an infective disease which requires treatment under general measures of disinfection, and particularly so when persons suffering from wounds are near at hand. Very serious consequences result from the infection of wounds, and women in confinement, with erysipelas.

It would appear, from the investigations of Lukowsky, Orth, and Fehleisen, that erysipelas is intimately connected with a micrococcus, which is smaller than that of vaccinia, and which abounds in the lymphatics of the skin at the margin of an erysipelatous zone.

The micrococcus was successfully cultivated by Fehleisen, who is stated to have produced typical erysipelas in the human subject by inoculation with the cultivated microbe. The vitality of the micrococcus is destroyed by antiseptics.

Phthisis (*Pulmonary Consumption*). Nearly 100,000 persons die annually from this disease in Great Britain, and it has been calculated that of all premature deaths, 26 per cent. result from disease of the lungs. Although the lungs are more particularly affected in this disease, the whole body becomes involved, and there is a gradual wasting away, or consumption, as it is termed. The disease may last only a few months, or it may drag its course over long weary years. Tuberculous consumption is

characterised by the formation of cheese-like matter, termed tubercles, in the lungs. They vary in size from a millet-seed to a bean, and occur both separately and massed together, and being deposited upon the surfaces they gradually cause the destruction of the breathing structure, a process which in course of time, unless arrested, results in death.

Tubercles are often found present in the expectorations (sputa) of consumptive persons, and there is practically no doubt that the disease is infectious to the extent that it may be conveyed by breathing an atmosphere contaminated with the virus or its products (tuberculous matter). Koch has concluded that "in all the morbid processes which, on account of their course as well as of the characteristic microscopical structure and the infectious properties of their products, must be considered true tuberculosis, there always occur in the tuberculous centres rod-like formations (tubercle-bacilli), which can be demonstrated with the aid of particular methods of colouring. This holds true both with the tuberculosis of man and of different animals." Koch, in fact, affirms these bacilli to be the specific cause of the disease, and he has performed the usual cultivations and inoculations which are deemed to furnish the necessary proof.

Klein,* however, disputes the identity of human miliary tuberculosis and tuberculosis of cattle, and finds that the bacilli found in the two affections are mor-

* *Practitioner*, August, 1884, p. 81.

phologically distinct, and are differently distributed. Neither does he agree with Koch, Watson Cheyne, and others, who maintain that "each tubercle owes its origin to the immigration of the bacilli, for there is no difficulty in ascertaining that in human tuberculosis, in tuberculosis of cattle, and in artificially induced tuberculosis of guinea-pigs and rabbits, there are met with tubercles in various stages—young and adult—in which no trace of a bacillus is to be found; whereas in the same section, cheesy tubercles may be present, containing numbers of tubercle-bacilli." What then seems to be absolutely proved beyond doubt is that tuberculous matter alone produces tuberculosis, but that tubercles do not owe their origin to the immigration of the bacilli. Is tuberculous matter, then, another non-living infectant?

It is worth mentioning that Schuchardt and Krause found tubercle-bacilli in fungoid and scrofulous inflammation, and other observers have found them in the tissue of lupus.

It should also be stated that Klebs, Toussaint, and Schüller maintain that tuberculosis is due to a micrococcus, and not to a bacillus at all. In the presence of such conflicting evidence what is to be believed?

At the same time, the experiments made by Dr. Burdon Sanderson must not be forgotten. He showed that in a number of guinea-pigs inoculated with pyæmic matter, and which outlived pyæmic poisoning, the lungs, liver, and spleen became tuberculous after a certain time; and he therefore regards it as "open to inquiry whether or not injuries which are

of such a character that air is completely excluded from contact with the injured part, are capable of originating a tuberculous process."

As regards the existence of the *bacillus tuberculosis*,* there can, it is said, be no doubt; but it is possible that it only acts in common with other irritants, and that consumption ensues only in those instances where the ground, so to say, is favourable for the propagation of the micro-organisms. That is to say, the germ itself may be, and probably is, ubiquitous, but it is only propagated in large numbers, and produces its characteristic products in the lungs of persons who are by numerous circumstances predisposed to the disease. In other words, phthisis may, perhaps, occur without tuberculosis, and, on the other hand, phthisical patients may become tuberculous.

Impure or imperfectly oxygenated air is considered to be particularly conducive to consumption, and, indeed, the causes may be stated to be all those which occasion debility, such as hereditary predisposition, want of proper nourishment, overcrowding, impure air, etc.

As regards the use of disinfectants† in connection with this disease, if we believe that consumption is

* Consult Dr. R. Douglas Powell's paper on "The Causative Relations of Phthisis," and the discussion which follows it. *Brit. Med. Journ.*, October 11th, 1884. Also paper by Dr. J. H. Bennett. *Ibid.*

† Compare papers by W. Williams, M.D., M.R.C.P., and J. Carrick Murray, M.D., *Brit. Med. Journ.*, July 23rd, 1881, and by A. W. Mayo Robson, *Brit. Med. Journ.*, June 21st, 1884. Also Lectures on Consumption, by Dr. Burney Yeo (J. and A. Churchill).

essentially tuberculous, and that tubercle is dependent on either a micrococcus or a bacillus, we must resort for a cure to a disinfectant which will arrest the development of the micro-organism without harming the host. Such an agent is sanitas oil, which may be used to keep the atmosphere of an apartment constantly aseptic, and the vapour also of which may be freely inhaled with impunity to the health of the patient. Whether or not it kills the micro-organisms in the lung-tissue, it can hardly fail to prevent their development and prevent putrefactive decomposition and fever.

The sputa of consumptive patients should, of course, be disinfected.

Acute Croupous Pneumonia is supposed to be caused by a micrococcus which can be conveyed in the sputum.

Relapsing Fever is of a periodic character, as its name implies, and only occasionally visits some of our large towns. It is sometimes called famine fever, which denomination it has obtained from the liability of the starving members of a population to be chiefly attacked. It attacks very suddenly, and is accompanied by shivering and chilliness, a white tongue, high temperature, and quick pulse. The temperature rises also towards the crisis, and often reaches 106°F. Its cessation is equally sudden with its onset.

The disease is a comparatively mild one, and is by no means dangerous if carefully attended. It is supposed to be caused by a spirillum, which is found in large numbers in the blood of persons during the onset

of the attack, but which is absent during the intervals. This micro-organism has not been cultivated outside the living body, although Vandyke Carter produced relapsing fever in monkeys by inoculation with human blood containing the spirillum.

Yellow Fever, an epidemic disease, which is attended with yellowness of the skin, hæmorrhage of the bowels, and delirium, has its habitat mainly in tropical climates. Occasionally it has occurred in Spain and France. As in typhus, one attack gives immunity from a second. It is not very, if at all, contagious.

Dr. Domingos Freire has given a report of experiments which are said to have established the facile transmissibility of yellow fever by inoculation, and the specific cause is said to be a cryptococcus. The same investigator claims, also, to have found a means of attenuating the virus of the disease, which consists in the cultivation of other micro-organisms known to be antagonistic to the cryptococcus.

Puerperal Fever, Pyæmia, Septicæmia, and *Blood-poisoning* are states of disease directly produced by the introduction into the system of poisons, of which the substance named sepsin (Burdon Sanderson) is illustrative. These poisons are elaborated by the micro-organisms which are found in putrid mixtures.

In puerperal fever, micrococci have been found in the form of zooglæa in all affected organs.

In septicæmia, Klein has found in the blood-vessels of the swollen mesenteric glands, large numbers of minute bacilli; and in gangrenous septicæmia around wounds, Arloing and Chauveau also found short bacilli.

In open wounds and closed ulcers, micrococci and bacilli are found in abundance.

The use of disinfectants, such as sanitas, for the purification of air and wounds largely contributes to the prevention of such complaints.

Woolsorters' Disease and *Malignant pustule* are said to be caused by a bacillus which also causes splenic fever or anthrax in cattle.

The spores of anthrax are of an extremely resistant character, but the fully developed germs are readily killed by a number of chemical reagents. It is probable that these micro-organisms are very widely distributed in nature, and that they only produce disease when they propagate under special conditions. Assuming, that is to say, that they produce disease indirectly by virtue of certain chemical poisons which they elaborate or secrete, such poisons are only produced under special conditions. It is almost certain that if admixed with antiseptic or disinfectant preparations under conditions which would otherwise lead to disease, they are innocuous.

That they indirectly lead to disease seems to be well proven.

In short, the life history of these low forms of life is a problem, of which the solution is yet far off. For instance, Klein states that by passing *bacillus anthracis* through different species of animals they become endowed with different properties. Thus, the blood bacillus of sheep or cattle dead from anthrax, invariably kills other sheep or cattle by inoculation; but after passing through white mice it loses this

virulence; a transitory illness is all that it can then produce in sheep or cattle. The explanation of this astonishing fact (if it be a fact) is altogether wanting: at first blush it would appear to indicate morphological change of the germs themselves, but this is a conclusion that cannot be entertained; and if the fact points to anything at all, it is to the conclusion that germs do not constitute *contagium vivum*, but only produce contagious poisons. It would be of the highest importance to make experiments with *bacillus anthracis*, similar to those conducted in connection with septicæmia by Burdon Sanderson; for example, to cultivate pure growths in different media, and make comparative tests of the effects produced in animals by inoculation; also to sterilise such mixtures in a way that would not chemically alter their composition, with the view of ascertaining if the effects were still producible, that is, whether they are due not to the bacilli, but to their products; and again, to mix disinfectants with the mixtures containing the cultivated bacilli, and ascertain then the effects of inoculation with the disinfected mixtures. It is by the application of such tests that, precise information concerning the disinfecting qualities of different substances is to be obtained. It is insufficient to test disinfectants by ascertaining their effects on the bacilli themselves. That is a matter, in my opinion, that more intimately concerns microorganisms than ourselves.

Malarial Fever.—This disease has been recently attributed by Klebs and Tommasi Crudeli to a bacillus

which occurs in the soil, and they produced by inoculation of rabbits a febrile disturbance which they considered to correspond with malarial fever in man; but this has been disputed by Sternberg upon the basis of experiments with material taken from the soil of malarious districts in America. Some further reference to this disease will be made in a later chapter.

Glanders is attributed to a peculiar bacillus, which was studied by Schütz and Löffler in 1882.

Swine Plague formed the subject of special investigation by Klein, who attributes it to a bacterium identical in morphological respects with *bacillus subtilis*. The respects in which they differ have yet to be ascertained. *Bacillus subtilis* is very widely distributed, but is considered innocuous.

Cattle Plague (Rinderpest).—Micrococci are supposed (upon the usual basis of cultivation and inoculation experiments) to cause this disease, but their specific nature is not considered well-established.

Gonorrhœa and *Syphilis* have been also attributed to micrococci, but according to the latest evidence (furnished by Welander*) proof of the pathogenic nature of the gonococcus is still wanting; while, as regards syphilis, the evidence is insignificant.

Some forms of *Sore throat* are also attributed by many microscopists to micro-organisms.

The poisons, whatever they be, that are associated with local ulcerations such as gonorrhœa, syphilis, and with diphtheric sore throat, gangrenous wounds,

* See *Brit. Med. Journ.*, October 18th, 1884.

and so on, are undoubtedly destroyed by chemical oxidants to the extent that they can be placed in contact with them, and in this clearly defined direction, therefore, the use of disinfectants (among them "Sanitas") in connection with these complaints is obvious. They are to be employed exactly upon the same principles that antiseptic surgery is practised.

The precise relations of micro-organisms to those diseases with which they are intimately associated have been discussed in a previous chapter, but I think we may usefully devote a little more attention in this place to the subject, and take as our text the very important contribution by Klein, to which already, many references have been made.*

For the purpose of testing some statements made by Sattler, Klein prepared an infusion of jequirity seeds (*Abrus precatorius*), and made a number of interesting observations therewith. Among other results he proved that the infusion contains a very poisonous principle, which produces violent ophthalmia when inoculated into the eye-balls of healthy rabbits, and that this principle is a natural constituent, having no relation whatever to the peculiar bacilli which can be cultivated in the infusion, and to the action of which Sattler had attributed the ophthalmia. This poisonous principle is destroyed by boiling, and comports itself something like the pepsin ferment. Warden and Waddell have lately isolated this substance, and name it abrin.

* The *Practitioner*, September and October 1884.

Klein then takes into consideration the method by which pathogenic micro-organisms produce disease, and after pointing out that their chemical influences on animal tissues are as yet unknown, and that even in artificial cultures their chemical effects have not been ascertained, he admits "it is quite possible that the pathogenic, like the zymogenic, organisms have this special character; that if the soil (animal body) contains a certain chemical substance, they are capable of growing, and thus capable of producing a definite zymogen or ferment." Although he admits this, he points out a distinction that exists between septic and zymogenic organisms, and pathogenic organisms, viz., the fact that the former two absolutely refuse to grow in the living tissue of a living animal; they can only grow where the once living tissue has become dead through the operation of other influences. After all, this distinction is but a matter of accident, in my opinion, for each micro-organism, irrespective of class, requires special conditions and substances for growth. In the absence of sugar, yeast cannot produce alcohol, and in the absence of alcohol the acetic ferment cannot, of course, produce acetic acid; so also, pathogenic organisms require certain conditions for their propagation; and it is a mere chance that such conditions are presented by living tissues. In this sense, it is absolutely impossible, by any number of successive artificial cultures, to clear a pathogenic micro-organism from any adhering chemical virus, because the micro-organism cannot live except in the presence

of suitable pabulum, and that condition being observed, it must give rise to new chemical products by its very life. Thus, although we may admit that pathogenic organisms originate specific diseases, it cannot be admitted that they themselves, by their mere presence in the living tissue, produce all the characteristic symptoms and consequences; but it stands to reason that they chemically alter some substances upon which they feed by the agency of a product that they immediately produce. Zymogenic and septic organisms cannot live in real living tissue, because it is, or it contains some chemical substance which is, inhibitory to their growth. The same substances may constitute food to other (pathogenic) organisms. In brief, a micro-organism cannot be identical with the virus of any disease; it can only produce the virus by a chemical change of a substance or substances present in the medium in or upon which it grows and multiplies.

Vaccination may be supposed to give protection either by introducing a chemical substance into the body, which is inhibitory to the infective process, or by the chemical alteration of parts of the body, enabling them to withstand the destructive process which is involved in small-pox.

Klein is forced to admit that pathogenic organisms act, in all probability, by the production of chemical poisons, but there he stops short, and does not apparently see that if this be so, then two further inferences must be made: in the first place, a pathogenic micro-organism can never exist apart from its virus,

for its life-function is identified with its production; secondly, since the virus is the true infectant, three classes of chemical substances can be employed in the treatment and prevention of specific diseases: (1) substances (true disinfectants) which chemically change and destroy the virus; (2) substances (antiseptics) which, by inhibition of the growth of the micro-organisms, prevent the production of the virus; (3) substances (germicides) which may be proved to be fatal to micro-organisms and their spores, if such substances can be found.

Germicides, if otherwise available, cannot be relied upon for the cure of diseases, for their introduction into the human body is as fatal to the host as to the parasites; and while they are equally poisonous as the true virus of any infectious disease, they may, for all that is known to the contrary, be without action upon the virus itself, even if the micro-organisms are killed off. In every sense, then, non-poisonous disinfectants of the two classes first-named are to be preferred, both for the prevention and the cure of infectious diseases.

Chemistry has, unfortunately, been too much neglected in all the recent studies bearing upon infectious and contagious diseases, and its application to them at the present time is perhaps the most patent requirement in the whole range of human wants.

Finally, it must be clearly understood that, so far, the connection between micro-organisms and infectious diseases has only been satisfactorily established

in a few cases, including septicæmia, relapsing fever, splenic fever, chicken cholera, glanders, swine plague, erysipelas, and puerperal fever. As regards consumption, malarial fever, leprosy, gonorrhœa, and rinderpest, there is yet no final evidence indicating the causes; while in respect of small-pox, scarlet fever, typhoid fever, typhus fever, cholera, diarrhœa, diphtheria, measles, whooping cough, chicken-pox, and syphilis, the information is still less precise in character.¶

That readers may not be altogether absorbed by the germ theory to the exclusion of all other theories of disease, I beg to refer them to chapter vii., in which there is given an account of the graft theory, as it is called, and also a study of the infective process witnessed in cancerous growths.

PART II.

CHAPTER X.

THE EUCALYPTUS AND ITS SANITARY PROPERTIES.

IN preceding chapters, attention has been directed to the putrefactive changes to which animal and vegetable matters are subject, and it has been shown that these changes are intimately associated with the causes of infectious diseases.

It has also been shown that many infectious diseases have their origin in putrefactive processes, while certain miasmatic diseases are both endemic and epidemic in places where organic matters are constantly undergoing change, as is the case with marshy and damp districts. It will now be our object to illustrate this last-named statement somewhat more fully.

In his "Letters on Chemistry" (p. 230), Liebig says: "In no case may we so securely reckon on the occurrence of epidemic diseases as when a marshy surface has been dried up by continued heat, or when extensive inundations are followed by intense heat;"

and in the Appendix to the same treatise there are recorded the following historical observations, which lend great weight to this view.

In constructing the railway from Strasburg to Basle, it was found necessary to excavate certain fields to a depth of two or three feet, thus causing a number of hollows in the neighbourhoods of Bollweiler and Feldkirch. In spring and autumn, these hollows filled with water, and this partially drying up in the summer, created perfect morasses, abounding in the infusorial life characteristic of stagnant water. Thus, there was introduced intermittent fever into the neighbourhoods, and year after year the epidemic became worse and worse.

In 1843, of the 1446 inhabitants of Bollweiler, 36 were attacked with intermittent fever; 166 cases occurred in 1844; 743 in 1845; and 1166 in 1846. The mortality increased in a corresponding proportion.

Again, in 1843, of the 480 inhabitants of Feldkirch 2 were attacked with the same disease; 20 were attacked in 1844; 135 in 1845; and 376 in 1846; and the annual mortality rose from 11 to 18.

These particulars were augmented and confirmed by similar facts embodied by Drs. Weber, Sänger, and West in a report to the Prefect of the Upper Rhine.

Under these circumstances, Dr. Dollfus-Ausset appealed to the Paris Academy of Sciences to use its influence and knowledge in instructing the administration concerning the best means of checking

the plague which had already decimated two villages, and was then threatening others.*

It does not, however, call for any such special cases to prove the source of malarial fevers. It is an observation which has grown with the world in age, that wherever there is matter of animal or vegetable origin in course of putrefactive change, danger to human health is also lurking in the water and floating in the surrounding air. It has already been explained that the mere rapid oxidation of organic matter is a comparatively innocuous process; and it is only when that normal process of change is substituted or accompanied by putrefaction that danger arises. The mere presence of organic matter in the soil does not necessarily indicate danger to the neighbourhood, because, supposing the soil to be of a porous nature, and in free contact with the air, the organic matter is very rapidly oxidised into innocent compounds—innocent compounds, that is to say, so far as infectious disease is concerned.

In writing of the effects of the surface of the soil on air, Dr. Angus Smith used these words: † "If soil affects the atmosphere, how does it happen that it is such an excellent disinfectant? Substances are not purified in the air to the same extent in the same time as in the soil. The great amount of surface in the porous soil is the cause of the rapid action mainly, but the acid humates act, and probably other substances, chemically. There are modes of

* *Comptes Rendus*, Séance du 5th March, 1847, p. 779.

† "Air and Rain," p. 507.

oxidising in the air beyond the power of ordinary oxygen; one of these is by means of nitrogen oxides, and another by ozone; but even these require great time and space. If we throw sulphuretted hydrogen water or its compound with ammonia on a few inches of soil, it passes through, oxidised in a few minutes; we obtain such an action in the air only in great volumes, although in the end the work done may be better for its purpose." Nevertheless, as shown when treating of sewage-disposal by irrigation, it is possible to overload even those gravelly and porous soils which oxidise the most rapidly. That is to say, it is possible, in a given case, to have more organic matter than, under existing circumstances, admits of oxidation in a certain time; putrefaction is the first result, and this may lead on to intermittent fever and other diseases.

Again, Dr. Angus Smith truly says* that "There seems to be a confusion in many minds between peat-bogs and marshes, but the difference is very great. No peat-bog gives out marsh fevers and agues, although the cold and wet may induce rheumatism. The acid peat prevents decomposition, and so removes all the results of putrefaction, which some people suppose to be the origin of the evil in marshes."

The miasms of marshes, then, are matters which accompany the processes of decomposition comprehended in the term "putrefaction."

Klebs and Tommasi-Crudeli (*Practitioner* for August

* "Air and Rain," p. 520.

1879) claim to have established malarial fever to be due to the action of *Bacillus malariæ*, as they name the micro-organism which they have detected in the soil and air of malarial districts. They found that the malarial poison exists in quantity in the soil of malarious districts, even at times when man is not affected with the disease, and that the poison may be detected at such times in the strata of air immediately above the soil. What is remarkable among the results of Klebs and Tommasi-Crudeli is, that they find large quantities of water render the germs inactive! Their method of experiment consisted in subcutaneously injecting liquids obtained from the soil into animals, and noting the rise of temperature experienced. This was from the normal one to 41·8°C. Similar observations were made with the so-called artificially cultivated germs. The doubt attached to the interpretation of such experiments lies in this—that the subcutaneous injection of many solid matters would probably produce corresponding results. Even these investigators found that the fluid freed from the bacillus produced an intermittent increase of body temperature!

The bacillus is developed in the presence of free oxygen, and thus belongs to the *Aerobii* of Pasteur.

According to Marchiafava, *Bacillus malariæ* also occurs in the blood of patients suffering from malaria, but Sternberg has stated that the febrile disorder produced by inoculating rabbits with material derived from the soil of malarious districts in America, has nothing in common with the human intermittent

fever, and can be induced, indeed, by other bacilli.* Apart, however, from the doubt that exists as to the precise relation between malarial fever and the *bacillus* observed by Klebs and Tommasi-Crudeli, there can be no question that the real virus is a chemical poison originated by micro-organisms during a putrefactive or allied change in organic matter contained in soil. In this respect they may be supposed to comport themselves just as do the micro-organisms in putrefying flesh; that is to say, they elaborate under suitable conditions products of chemical decomposition, which by their reception in the human system initiate disease. In decomposing flesh, sepsin is produced, and it is the active virus in septicimiæ; whereas in decomposing vegetable matter present in soil a hypothetical substance is produced, which may be termed malarin, and it constitutes the active virus of malarial fever. The micro-organism studied by Klebs and Tommasi-Curdeli may possibly be the originating cause, but that is not finally proved.

Having said so much by way of preface, we may at once proceed to the more immediate purpose in view, viz., that of describing the sanitary properties of the *genus* eucalyptus.

The *Eucalyptus globulus* was discovered † by Labillardière, in the Island of Tasmania, in 1792;

* Klein on Micro-organisms and Disease, *Practitioner*, June 1884, p. 415.

† See Professor Bentley's (1874) lecture on the Eucalyptus Globulus, and his more recent one printed in the *Pharm. Journ.* for March 4th, 1878.

but its fever-destroying characters first attracted the attention of M. Ramel in 1856. In this year he sent some of the seeds to Paris, and in later years forwarded further supplies, claiming for it, at the same time, the power of destroying the miasmatic influence of marshy districts. Considerable credit is also due to Baron Sir Ferd. von Mueller (the Government botanist in Victoria), who originally brought the *Eucalyptus globulus* to the notice of M. Ramel; and a meed of praise is also merited by Sir W. Macarthen, of Camden, Sydney, Australia, who also exported some seeds in 1860, and claimed anti-miasmatic properties on behalf of the tree.

Since this now well-known tree was first brought before the notice of the public, its fame has been a rapidly increasing one, the evidence in its favour forming an almost unbroken chain down to the present time.

In a memoir by Prof. Gubler,* there is given particular testimony to the fact that this so-called "fever tree," or "fever-destroying tree," exercises extraordinary effects in regard to intermittent fever. It is pointed out that, in marshy districts near eucalyptus forests, the fever is practically unknown, and this state of things is attributed to the aromatic vapours which emanate from the tree, and the preservative powers of the branches and leaves which fall upon the marshy soils. It was upon the basis of this knowledge that the Algerian and Corsican

* *Journ. de Pharm. et de Chimie*, December 1871. (*Pharmaceutical Journal*, New Series, vol. ii., p. 703).

plantations, of which more will be said hereafter, were made.

In 1871, M. Raveret-Wattel published a report* to La Société d'Acclimatation, in which he said: "Science is far from having said her last word respecting the part that may be played by these useful plants,"—meaning the eucalypti; and these words have since been verified in a singular manner. In his report, M. Raveret-Wattel specially dwells upon the importance which M. Ramel attached to the sanitary power of the eucalyptus, and points out that it was very much doubted when first claimed. He thinks, however,—and justly so,—that the plantations which were effected in the most unhealthy parts of Algeria have quite established the correctness of M. Ramel's views. The endemic fever in these districts is stated to have been perfectly annihilated by the plantations in question; and the use of an infusion of the leaves of the tree became so popular as a remedy against fever (even in many cases where quinine is said to have been administered in vain), that M. Alurmada had his trees completely stripped of their bark by the populace. M. Raveret-Wattel adds that the oil of eucalyptus will no doubt become very useful as a remedy in putrid fevers, and for application in cases of fœtid suppuration, etc.

In a paper contributed to the Californian Academy of Sciences,† in July 1872, by Mr. R. E. C. Stearns,

* *Pharm. Journ.*, New Series, vol. iii., pp. 22 and 43.

† *Western Lancet*, vol. i., p. 696; *Pharm. Journ.*, vol. iii., p. 603.

the author quotes from a letter written by Dr. A. B. Stout, in which occur these words:—"There can be little doubt but that the oil of eucalyptus, when it can be procured, will be an available remedy against malarious diseases of all types, and that the presence of the trees cultivated in gardens, contributes to sanify the atmosphere from those emanations which give rise to epidemic diseases."

As already stated, the anti-miasmatic power of the grown-up eucalyptus was particularly tested in Algeria, and the results were communicated by M. Gimbert to the French Academy of Sciences.*

The report instanced the case of a farm situate twenty miles from Algiers, and notoriously known to possess a pestilential atmosphere, in which 13,000 trees were planted with the effect of absolutely stamping out the previously endemic fever.

A Dutch landed proprietor also planted a number of eucalyptus trees on the banks of the Scheldt, where he owned some property in a very malarious district. The effect was, that the particular spot was rendered quite salubrious, while the surrounding neighbourhood remained as fever-stricken as originally.

A further and an interesting contribution to the history of the eucalyptus in Algeria was made a few years since,† to the pages of the *Pall Mall.* The writer points out that, it was only so recently as 1867 that the Algerian plantations became at all

* See *Pharm. Journ.*, vol. iv., p. 494.

† *Pharm. Journ.*, vol. iv., p. 781 (taken from the *Pall Mall*).

extensive in character, and then he goes on to describe what he himself had witnessed but a few days prior to writing. He had visited the estates of M. Ramel, M. Trottier, and M. Cordier, whose trees had all been grown from seeds. On M. Trottier's estates at Hussein Dey, the trees were fifty feet high. "In this evergreen wood, all around us were tall reddish smooth stems, with the bark hanging down in a ragged, untidy manner,—for the tree sheds its bark in winter,—and grey, willow-like leaves were waving on flexible boughs. . . . . It produced a curious impression to walk in the dim twilight of this Australian-African forest, and to think that this was also a wood of the miocene period. Beautiful is not the word I should apply to its appearance; but in exchange for bare sun-baked earth or deadly swamps, I must say these eucalyptus forests are most grateful, and the smell delightfully resinous, warm, and gummy . . . . There seemed to be a general impression that the eucalyptus was a fever-destroying tree, and of the greatest importance to the colony from that point of view."

I have not been able to obtain any reliable figures as to the distribution of the eucalyptus tree in various parts of the world, although from the text it is seen that it is now very widely distributed; plantations having been established all over the world. Thus, in South California, the *Eucalyptus globulus* is now planted by thousands, and it has been estimated that the gain in growing the timber is even a greater one than that derived from cereals.

Mr. Bosisto, the well-known distiller of eucalyptus oils, has given some idea of the extent of area covered by eucalypti in Australia,* and its freedom from fever. He says, four-fifths of Australian vegetation consists of the eucalyptus, and the country, on the whole, may be said to be pretty free from violent endemic or miasmatic poisons: indeed, he adds, "they might be said to exist only as the eucalyptus receded."

Now, in his report to the Commissioners of the Exhibition, Mr. Skene, writing of Victoria, states that the area of the whole colony amounts to 55,644,000 acres. Of this 5,560,000 acres are covered with dense mallee scrub; 6,225,000 acres consist of mountainous ranges, deeply wooded with gums; while the area of the open timbered country amounts to 38,922,000 acres. Upon the basis of these figures Mr. Bosisto calculates that the extent of mallee country in New South Wales and South Australia is twenty times that of the area in Victoria.

From these and other considerations, which will be dealt with presently, Mr. Bosisto also concludes that the eucalyptus is established beyond all doubt as a fever-destroying tree.

Italy has also furnished its evidence upon this question. In a paper read before the Roman Academy of Medicine, on April 30th, 1876, Dr. Fedeli† alleged that wherever plantations of the eucalyptus

* *Pharm. Journ.*, vol. v., p. 270, from a paper read by Mr. Bosisto before the Royal Society of Melbourne.

† *Pharm. Journ.*, vol. vi., p. 912.

existed, malaria is unknown, and where the malaria has been endemic the cultivation of this tree suffices to mitigate in all cases, and in some instances to entirely remove, the disease. A long discussion followed the reading of Dr. Fedeli's paper as to the specific manner in which the eucalyptus exercises its powers; but while different views were taken of this question, the testimony borne to the febrifugal virtues of the eucalyptus was perfectly unanimous.

It is of interest to note that since the reading of Dr. Fedeli's paper, the Italian government has supplied landholders with large quantities of slips of the tree for forming plantations in all malarious districts.

According to recent reports, 500,000 eucalyptus trees are to be planted in Mexico as some kind of protection against yellow fever, and with the view of modifying the rainfall.

At a recent Easter Réunion at the Sorbonne, Dr. de Pietra Santra, a delegate from the Climatological Society of Algiers, recited some of the results of the investigations made in Algeria with the view of determining the value of the eucalyptus in its relation to public health. The reports received from fifty localities, boasting the possession of more than 1,000,000 trees, show, in the first place, that the eucalyptus exhibits a sanitary effect of the most unquestionable nature; secondly, that wherever the tree is cultivated, the intermittent fever decreases both in intensity and frequency; and lastly, that large tracts of marshy and uncultivated lands have

been rendered healthy, and indeed quite transformed, by the agency of the eucalyptus. Dr. de Pietra Santra also stated that in Corsica, where more than 600,000 plants are growing, similar experiences have been observed.

Between Nice and Monaco there existed, until recently, such a very unhealthy district, that the Paris, Lyons, and Mediterranean Railway Company were compelled to change their watchmen who did service at a crossing in the neighbourhood, every few months. Some time since, however, a plantation of the *Eucalyptus globulus* was made there, and now there is said to be no more fever; and the necessity therefore for perpetual change of watchmen (to prevent death) is abolished.*

There is yet one other instance† of the wonderful hygienic properties of the eucalyptus which may be mentioned here, although briefly. In a desolate part of the Campagna there stands an old monastic institution upon a spot consecrated by tradition as that whereon St. Paul was martyred. For centuries this part of the Campagna was a stronghold of pestilential fever, and prolonged residence in the monastic institution, in question, surely led to death. Some few years ago, a band of Trappist monks planted the eucalyptus in its cloisters, and the trees are now more than thirty feet in height. What is more important, however, is that the place is now once more habitable, and fever reigns there no more.

* *Chem. News*, December 22nd, 1876, from *Le Mondes*.

† *Pharm. Journ.*, vol. vi., p. 624.

That this effect is due to the eucalyptus plantation there can be but little doubt. It is true that the place was the execution-ground and burial-place for criminals of old Rome, and that 700 cart-loads of human bones have been removed. Moreover, the ground around has been deeply cultivated, thus assisting to make the spot habitable. But in spite of all this, and even if bones have been removed, it cannot be supposed that at this remote time from the days of old Rome, any organic substance forming part of the once buried bodies could have remained in the soil and have successfully resisted combustion by the atmosphere. Bones, themselves, are for the most part inorganic and harmless, and it would be more reasonable to look for malarial fever at Kensal Green than to search for it in an old Roman burial-ground, so far as it may be connected with the burials that have taken place at either locality. No doubt the fever which once infested the Trappist Monastery at Tre Fontane, near Rome, has been overcome by general sanitary measures, but foremost among these was the cultivation of the eucalyptus tree.

Dr. Laughlan Aitken, of Rome, has recently called in question * the value of the plantations at Tre Fontane, although he admits that they have been kept in a flourishing condition by the zeal and activity of the Trappist monks, who add to the revenue of the monastery by the sale of eucalyptus elixir which they prepare. Any improvement, he

* Letter to *Brit. Med. Journ.*, September 27th, 1884.

states, which may be claimed, is due quite as much to the necessary subsoil draining and preparation of the ground as to any influence of the young gum trees. That may be so, but I think that Dr. Aitken might, without damaging his scientific reputation, give credit to the value of the eucalyptus tree so far as it has been substantiated by good chemical and other practical evidence, and be it added that such evidence is not wanting.

Professor Tommasi-Crudeli, of Rome, is also of opinion that plantations of the eucalyptus are of no value* in preventing the occurrence of malaria. He has cited several instances from his experience in the Campagna, where these trees had been used, and where they had for a long time given perfect satisfaction, until suddenly in 1882 a severe attack of malaria occurred, while other districts where malaria used to manifest itself were free from attack. Such an experience really proves very little, because malarial fever is an infectious disease, the poison of which may be conveyed in the air and in water, and in order to obtain general protection against attack, it would be necessary to have plantations of the eucalyptus covering the whole area under observation, and shutting off contamination from exterior sources. The eucalyptus certainly gives some protection, even if absolute immunity cannot be claimed for it.

This protection is mainly due to the essential oil

* See his address to the International Medical Congress, 1884 *Brit. Med. Journ.*, August 30th, 1884.

which is given off in a vaporous condition from the trees, and to the products of its atmospheric oxidation in presence of moisture; but it is also due in part to the action of the tree in absorbing water from the soil. The shoots of the roots throw out thousands of thread-like fibres, forming a dense sort of woolly mat, which suck up a great quantity of water, and that which is not utilised in the rapid growth of the trees, is ultimately evaporated with the essential oil from the leaves.

All quarters of the globe have furnished evidence * of the sanitary value of the eucalyptus, and no one who is open to conviction, can fairly withstand the conclusion that has been arrived at, after the study and experiments of the last half century, which is to the effect that the *genus* is both fever-preventing and fever-destroying. Any doubt, however, on this matter, will probably be removed by the chemical evidence to be subsequently submitted.

In addition to the direct evidence as to the hygienic importance of the eucalyptus already adduced, there is a large amount of indirect evidence leading to the same conclusion, and it is important enough to be briefly described in this place.

In his various papers, Dr. Gimbert of Cannes has directed attention to the fact that the oil of eucalyptus is not merely of a pleasant balsamic nature, but that it speedily removes all unpleasant odours. Moreover, he used the leaves largely, instead of lint,

* See also Consul Playfair's Report on the Febrile Virtues of the Eucalyptus, 1877.

for dressing wounds, with very satisfactory results, and showed that when eucalyptus oil is mixed with albumin or fresh fibrin, putrefactive change is entirely prevented.

M. Gubler, also, has given testimony to the value of tinctures, infusions, and decoctions of the oil in surgery; and M. Mare used fresh young leaves to stimulate small wounds which were slow to cicatrize, and employed an aqueous infusion with great success in purulent catarrhal affections of the urethra and vagina. In consequence of these and similar observations, a large quantity of the alcoholic tincture of the leaves has been exported from Australia during late years for use in European countries.

Then again, Mr. Stearns has compared the disinfecting properties of oil of eucalyptus with those of carbolic acid, and writes:—"Its chief value, however, is as a sedative and antiseptic in asthma and throat diseases, nasal catarrhs, and affections of the mucous membranes." In his own investigations he used both the alcoholic tincture and the spray of the pure oil.

Dr. Gimbert found that the oil of eucalyptus and its various preparations diminish the vascular tension, and from inducement of a sense of comfort, tends to bring about sleep.

The success which attended the use of the same preparations in mitigating and curing ague, etc., led to the idea that the leaves of the eucalyptus contained some alkaloidal principle identical with, or similar to, quinine. This idea, however, was refuted

by the experiments of Mr. Broughton, the Government chemist of Ootacamund, and later on by M. Rabuteau.* Mr. Broughton examined the leaves and bark, and states that neither quinine nor the other alkaloids of cinchona bark exist in the plant in any proportion. M. Rabuteau established the absence of all other alkaloids.

It is on record that in the Mauritius an infusion of the leaves of the eucalyptus was used with such great success in the treatment of malarial fever on one occasion, that the leaves were sold at sixpence each!

Another application of the eucalyptus was discovered in its effects upon rheumatic complaints: "Branches and leaves are put into hot water, and I am assured by those who have tried it that such baths remove rheumatic pains, neuralgia, and the debility left by the malaria incidental to the country." †

Again, at a meeting of the Paris Société de Pharmacie, on Nov. 4th, 1874, M. Vidal communicated a note on the vermifugal characters of essence of eucalyptus when employed in the form of an enema, and gave details of the case of a Zouave who was afflicted with the presence of a number of *oxyuris vermicularis*, which all ordinary vermifuges had failed to remove. He was completely cured in nine days by

* *Comptes Rendus*, lxxv., 1431.

† Quoted from the contribution to the *Pall Mall* previously referred to.

using each evening an enema containing from fifty to sixty drops of the oil to a quart.*

A watery infusion of eucalyptus leaves is known in France to be so useful in medicine and pharmacy, that it is now to be found in the French Pharmacopœia.

The mere preservative properties of oil of eucalyptus are well known; and since the date of my own earlier researches, they have been also investigated by Mr. T. Taylor.† He found that, although the oil of eucalyptus is but sparingly soluble in water, yet such a solution has powerful antiseptic and deodorising powers, and is capable of considerably retarding certain fermentative changes and the putrefaction of albuminoids. He says: "The fleshy sides of the skins of animals may be preserved from putrefaction by rubbing on them eucalyptus oil. It may also be combined with plaster and injected into the veins and arteries of animals for the purposes of preservation."

The anti-miasmatic power of eucalyptus and pine forests has been long supposed to have some connection with the volatile oils which are naturally secreted by them, and which find their way, by evaporation, into the atmosphere. But in explanation of these results, it has been generally held that the volatile oils have the power, in some way, of

* *Pharm. Journ.*, vol. v., p. 474.

† *Ibid.*, January 12th, 1878, being an extract from the Report of the United States Commissioner of Agriculture.

giving rise to ozone—a substance which, judging from its chemical properties, may be supposed to oxidise, or burn up, the malarial matter infesting the soil and atmosphere of marshy districts.

Mr. Taylor admits that the oxidant need not necessarily be ozone; he is, however, quite satisfied that the oils of eucalyptus and turpentine, etc., do exhibit oxidising effects, and he cites experiments in support of this view. Some further extensive investigations will be described hereafter, and it will then be seen what truth there is in this view.

In connection with the salutary properties of pine and eucalyptus forests, and before we attempt an explanation, it will be of interest to take notice of a few facts which have become matters of general experience; facts which, known from very early times, have come down to posterity without any adequate explanation.

For instance, it has been known for ages that the atmosphere of pine forests is most favourable to invalids suffering from pulmonary affections, and even at the present time it is customary to send invalids to breathe the exhalations of the coniferæ. Such exhalations are generally, although quite erroneously, supposed to be strongly ozonic in character.

Dr. Cornelius Fox, in his very interesting work on Ozone, dwells also upon this subject, and alludes to the fact recorded by Herodian, that, "in a plague which devastated Italy in the second century, strangers crowding into Rome were directed by the physicians to retreat to Laurentum, now San Lorenzo,

that by a cooler atmosphere, and by *the odour of laurel*, they might escape the danger of infection." *

Referring also to certain investigations on the hygienic utility of essences and perfumes, about which I shall have something to say also hereafter, Dr. Fox says they "demonstrate that the disciples of Empedocles were not in error when they planted aromatic and balsàmic herbs as preventives of pestilence." The investigations to which Dr. Fox is here referring were directed to the supposed production of ozone by the atmospheric oxidation of essential oils; and, continuing his observations upon this subject, he goes on to say that, "The ancient custom amongst physicians of furnishing the handles of their canes with vinaigrettes, the fumes of which might protect them from the noxious exhalations of their patients; and the old practice of strewing aromatic herbs, such as rue, before filthy prisoners in the dock of a criminal court, so that the olfactory nerves of the lawyers might be offended as little as possible; as well as that of providing the chaplain with a bouquet when accompanying a criminal to Tyburn, lose their absurdity under the light of these investigations. The efficacy of certain perfumes in warding off disease during exposure to fœtid air, which was thoroughly believed in by our ancestors, may be, perhaps, explained by the researches above referred to." †

* "Ozone," p. 121. By Dr. Cornelius Fox.

† "Ozone," p. 122.

Patchouli oil is produced in enormous quantities, and is sent direct to Mecca, the Arabs believing in its health-giving properties and the protection it affords against infection.

We have then, again, the case of camphor, which from time inmemorial has enjoyed a reputation as an antiseptic, and which is, to this day, worn by thousands of persons about their clothes as a protective against infectious diseases.

Lastly, the efficacy of wooden hospitals in inducing the rapid convalescence of patients has been supposed to be due—at least partly—to the resinous and turpentine-like substances existing in the wood, and which, by their evaporation into the atmosphere, pass, by way of the breath, into the patients' bodies.

Reviewing now the facts recited in the foregoing pages, we are presented with a mass of indisputable evidence, showing: firstly, that the eucalyptus tree prevents malarial fever; secondly, that the oil of eucalyptus also exhibits peculiar vermifugal, antiseptic, and disinfecting properties; thirdly, that pine forests exercise important hygienic influences; fourthly, that turpentine, camphor, and other products generated naturally in pine forests, also possess certain properties which render them valuable as sanitary appliances.

Even if we allow a fair margin for any pardonable, but perhaps inevitable, exaggeration on the part of the different authorities whose investigations have been cited and referred to, and put down a certain number of results as doubtful, and some of the con-

clusions as erroneous, there yet remains abundant evidence of the hygienic value of eucalyptus and pine forests,* and a large amount of positive data regarding the antiseptic, disinfecting, and healthful properties of certain products natural to these forests. What is still more striking, there is an intimate relation between the hygienic value of the pine and that of the eucalyptus; for not only are both trees healthful, but their products exhibit similar properties and are chemically allied. How far this resemblance holds good on further investigation, and the extent to which the hygienic properties of these trees is connected with the volatile oils furnished by them, will be fully studied and demonstrated in the ensuing chapters.

* Although slightly foreign to the object of this work, it is of interest to bear in mind that the sun-flower is stated to exhibit anti-malarial characters. The following paragraph in connection with this subject appeared in the *Pharm. Journ.*, November 29th, 1879:—

"In a St. Petersburg weekly medical journal (quoted *Pharm. Zeit. f. Russl.*, October 15th, p. 623), P. Filatow reports that in the provincial hospital of Ssaransk, during the last three years, an infusion of sun-flower (*Helianthus annuus*) has been used in numerous cases of intermittent fever, and in most of them with results as certain and satisfactory as those following the use of quinine. The 'infusion' used was prepared by digesting sun-flower stalks, cut into small pieces, during three or four days in eight parts of ordinary brandy; it is described as being then of the colour of sherry and tasting of sun-flower. The dose for adults was a table-spoonful three times a day, and the action is said to have been equally favourable whether administered before or during the paroxysm of fever. In fresh cases of fever, the cure was completed in from one to three days, but in more confirmed ones, the use of the infusion required to be continued during a week or longer."

Perhaps the sun-flower yields also an essential oil which is volatile.

Since the first edition of my book was published, eucalyptus oil has been adopted by Sir Joseph Lister for use in antiseptic dressings, in place of carbolic acid. He found that its antiseptic properties are quite as reliable as those of phenol, while it is free from irritating and toxic effects. Its volatility, while being advantageous in other respects, tells against its use to some extent, for gauze prepared from the oil may lose its strength by keeping.

The testimony of Sir Joseph Lister to the value of eucalyptus oil as an antiseptic for use in surgery, is supported by the results of Professor Schulz and Dr. Siegen * of Deutz, and by its more or less general use.

Sanitas oil, which is obtained by the atmospheric oxidation of turpentine, is, however, far superior to oil of eucalyptus, and is now being largely used as in antiseptic dressing.

The value of eucalyptus oil formed the subject of a publication by Professor Hugo Schulz, of Greifswald, in 1881,† in which is brought together a great deal of recorded information respecting the chemical, physiological, and medicinal properties of this substance; but my own researches on the limited oxidation of essential oils (including eucalyptus), and the study of the antiseptic and disinfectant properties of

* *Lancet*, September 4th, 1880.

† The reader may also consult with advantage the articles forming a review of that book by Baron Sir Ferd. von Mueller, contributed to *The Australian Medical Gazette* for October, November, and December, 1888.

the products, were conducted and published long before that date. They will be fully detailed hereafter, and I will only add, here, that through the oversight or the neglect of my investigations, Schulz gave himself a great deal of unnecessary labour, and after all, elaborated an erroneous chemical theory regarding the oxidation and action of eucalyptus oil.

CHAPTER XI.

ESSENTIAL OILS AND THEIR ATMOSPHERIC OXIDATION IN NATURE, THE LABORATORY, AND THE FACTORY.

IF we seek to establish the precise way in which the eucalyptus and the pine exert their hygienic influence, we are forced by exclusion to consider it mainly in relation to the essential oils naturally formed in these trees, and to the emanation of which, in a vaporous condition, they owe their grateful fragrance. We may ignore in this place the drainage power of the trees, because, although this is a valuable feature with them, it is one which does not concern present considerations; and moreover, it is common to all trees, although particularly exhibited in those which, like the *Eucalyptus globulus*, grow so rapidly. Any sanitary effect due to mere drainage of water from the soil is of a purely negative character; whereas the hygienic influences of the pine and eucalyptus are of a positive character. These trees are healthful in themselves, and the emanations which they diffuse into the atmosphere, are specifically efficacious both as regards protection from the malarial poison and its destruction, as also for the cure of lung diseases. What, then, is the nature

of this influence? is the question that must now be solved.

It was for a long time supposed (and Professor Schulz fell into this error) that the oils to which plants and flowers owe their perfume, when exposed to the action of atmospheric oxygen, influence it in such a way that ozone is produced; and hence it is stated, in most of the older treatises on chemistry, as a fact, that ozone is produced. It was beyond dispute that an active agent resembling ozone in its properties is formed in this way; but the actual nature of this agent was (until established by my researches) entirely an open question.

There was a great difficulty, however, in strictly diagnosing ozone from peroxide of hydrogen; and as the last-named substance was practically unknown outside the laboratory, whereas ozone was known to occur naturally in the atmosphere, the assumption, which came to be regarded as an established fact, was somewhat excusable.

Schönbein, who was the great authority at that time upon ozone, thought that oil of turpentine gives rise to ozone by contact with air, and by-and-bye others taught this as a fact, and thus it passed into the text-books. For instance, it is stated in Gmelin's Handbook, and in the earlier editions of Miller's "Elements of Chemistry." Lawes, Gilbert, and Pugh expressed their belief that the supposed ozone existing in the vicinity of vegetation is due to the oxidation of the hydrocarbons evolved by plants;*

* *Journ. Chem. Soc.* (2), 1, 1863, p. 100.

and in a paper communicated to the Royal Irish Academy on January 9th, 1871, Professor C. R. Tichbourne stated that when light resin oils are exposed to the action of the atmosphere under the influence of light, they produce an abundance of ozone, the boiling point of the oil being raised simultaneously. This last fact may be at once explained: the oil absorbs atmospheric oxygen, giving rise to the formation of oxidised compounds which boil at a higher temperature than the original hydrocarbons: peroxide of hydrogen (not ozone) is a characteristic product of the oxidation.

It is not surprising that the difficulties which Schönbein and Berthelot (who also examined the oxidation of oil of turpentine) could not overcome, should also have misled others in more recent times.

Thus, Professor Paolo Mantegazza* arrived at the conclusion that a large quantity of ozone is discharged by odoriferous flowers, including those of the narcissus, heliotrope, hyacinth, and mignonette. Similarly, he concluded that among plants, the cherry-laurel, clove, lavender, mint, lemon, and fennel produce ozone as well as the following perfumes; eau-de-cologne, oil of bergamot, extract of millefleurs, essence of lavender, and the oils of nutmeg, aniseed, thyme, peppermint, etc., etc.

In the well-known treatise on Inorganic Chemistry by Eliot and Storer,† there occur the following words:

* *Rendiconte del Reale Instituto Lombardo*, vol. iii., fasc vi.

† Second Edition, 1868, p. 145. Van Voorst, London.

"The disinfecting power of ozone is interesting in connection with the observed facts, that ozone is abundant in the air of pine forests, where turpentine abounds, and that pine forests are, as a general rule, remarkably free from malaria."

At the time when that treatise was written, chemists knew no better regarding the nature of the active principles engendered by the oxidation of turpentine. In 1878, however, and indeed long before, there existed better knowledge of the subject, and hence it is somewhat surprising that the old error should find its way into the generally excellent "Treatise on Chemistry" by Roscoe and Schorlemmer.* They write: "Turpentine and several other essential oils, when acted upon by atmospheric oxygen, transform a portion of it into ozone,"—whereas they do nothing of the kind.

So also, Dr. Moffatt† has published a number of papers in which it is stated that he has found the oils of juniper and turpentine, etc., to produce ozone by contact with the air.

H. Fudakowski‡ and E. Schaer,§ and numerous other chemists, have made the same mistake.

When I commenced my examination of this subject about the summer of 1871, I was not acquainted with any of the publications of the late Dr. Day of Geelong; but late in 1875, and when I had arrived

* Published in 1878. Second Edition, p. 200.

† See *Sanitary Record*, October 26th, 1877.

‡ *Deut. Chem. Ges. Ber.*, vi., 106-109.

§ *Ibid.*, vi., 406-410.

at and published my main results, they were brought to my notice. Dr. Day made a large number of very interesting observations upon various essential oils and certain fatty matters in which he had noticed the formation of an active agent resembling peroxide of hydrogen in its properties; but the tests which he employed to detect it are equally influenced by ozone; and moreover, as he seems in his papers, published before mine, to speak of the substance not only as peroxide of hydrogen, but also as antozone (as if this were a distinct substance), his investigations did not materially advance our knowledge of the subject in question. It will be seen that my object was not only to establish the exact nature of the active principle, but the actual method of its formation. In this I was happily successful.

It may, however, be at once admitted that Dr. Day with great intelligence applied his knowledge to the explanation of the hygienic influence exerted by the eucalyptus, and also by wooden hospitals. While this is readily granted, it must be understood that, after all, his experiments did not satisfactorily settle the vexed question as to whether ozone or peroxide of hydrogen is produced by the oxidation of the essential oils.

Moreover, in common with all others whose names have been mentioned in connection with the study of the hygienic properties of the pine and eucalyptus, Dr. Day totally ignored the formation of those organic compounds which I have since discovered to accompany peroxide of hydrogen as products of

oxidation, and to which the antiseptic powers of these trees is largely due.

With these preliminary observations it will now be of interest to describe my experiments in as simple a manner as the nature of the subject admits. Those scientific readers who wish to acquire a precise knowledge of the work can do so by consulting the publications* referred to below.

The plants which furnish essential oils in nature are very large in number, and comprise not only the members of the coniferous and aurantiaceous orders, but also the order *myrtacæ*. It is to the essential oils emitted by these plants at ordinary temperatures, or to products of their atmospheric oxidation, that their intense odour is due.

In the *umbelliferæ* the oil is most abundant in the seeds; in the *aurantiacæ* both fruits and flowers yield volatile oils; the *rosacæ* contain oil only in the petals, while the *myrtacæ* and the *labiatæ* supply it mainly from the leaves.

As is well known, many so-called essential or volatile oils, such as otto of roses, lemon, orange,

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* "On the Oxidation of the Essential Oils. By C. T. Kingzett."

Part i. *Journ. Chem. Soc.*, Ser. 2, vol. xii., p. 511.
,, ii. *Ibid.*, ,, xiii., p. 210.
,, iii. *Chemical News*, ,, xxxii., p. 138.
,, iv. *Ibid.*, ,, xxxiv., p. 127.
,, v. *Ibid.*, ,, xxxix., p. 279.

See also *Pharm. Journ.*, December 2nd, 1876; *Journ. Soc. Arts*, February 16th, 1877, and March 8th, 1878; *Brewers' Guardian*, September 18th, 1877; *Sanitary Record*, December 18th, 1878, and January 15th, 1880.

bergamot, etc., are prepared on a large scale for commercial purposes.

The essential oils mainly consist of hydrocarbons, —that is to say, substances exclusively composed of carbon and hydrogen,—but many of them contain, also, oxidised bodies which, at least in numerous instances, are formed from the hydrocarbons by the action of atmospheric oxygen and moisture. No doubt, many of the gums and resins which occur in nature are intimately related to the essential oils, and perhaps in some cases, indeed, derived direct from them.

Ordinary oil of turpentine, representing the hydrocarbon part of the essential oils of different kinds of pine tree (*Pinus maritima*, *Pinus australis*, *Pinus Tœda*, etc. etc.), when analysed, is found to contain 88·23 per cent. of carbon, and 11·76 per cent. of hydrogen; and these figures lead to the chemical formula $C_{10}H_{16}$ as representing the constitution of turpentine. The mere analysis alone is not sufficient to fix this as the true formula; it might be C_5H_8, or $C_{15}H_{24}$, or $C_{20}H_{32}$, all of which substances would give the same percentage composition. There are, however, other considerations, of which we shall say more presently, which fix the true formula of oil of turpentine hydrocarbon as $C_{10}H_{16}$. This is called "terpene," in order to diagnose it from other substances which accompany it in the crude oil.

Similarly, other terpenes, or hydrocarbons of the same empirical formula, have been obtained from the oil of lemon, sweet orange, eucalyptus, bergamot,

lime, neroli, coriander, juniper, caraway, camomile, hop, parsley, wintergreen, thyme, valerian, copaiba, cubebs, birch, elemi, etc.

There are other essential oils which, while they do not yield true terpenes, are yet intimately related to these substances. For instance, oil of cloves yields the hydrocarbon $C_{15}H_{24}$, oil of peppermint $C_{10}H_{18}$, and oil of roses $C_{10}H_{20}$.

Although the true terpenes are identical in composition, and are represented by the same formula, they yet comprise a certain number of distinct hydrocarbons; distinct, that is to say, in the sense that all their properties are not uniform, while some of them are common to all. The explanation of this fact is to be found in differences in the way in which the constituent atoms of the different terpene-molecules are arranged. Such facts are not at all uncommon, and are well understood in chemistry. For instance, carbon exists in the form of the diamond and as coke; oxygen exists also in the state of ozone; and other substances are capable of assuming various natural forms, although identical in mere matter.

A special property of all the terpenes consists in the avidity with which they absorb oxygen, either from the pure gas or from the atmosphere. In illustration of this fact, there are here reproduced two tables from my papers published at different times. The oils in question were placed along with known quantities of air or oxygen, in tubes sealed at one end; and after exposure under various circumstances for given periods, the amount of oxygen

absorbed * was measured by ascertaining the remaining amounts.

Name of Oil.	Cubic centimetres of oxygen absorbed.	In No. of days.	= Daily.
Turpentine—			
(*a*) in sunshine	220 from oxygen gas	6	36·6
(*b*) in shade .	20 ,, ,, ,,	36	0·6
Caraway . .	18 ,, ,, ,,	6	3·0
Bergamot . .	12 ,, ,, ,,	4	3·0
Juniper . .	5 ,, ,, ,,	2	2·5
Cubebs . .	4 ,, ,, ,,	2	2·0
Lemon . .	16 ,, ,, ,,	13	1·2
Naphtha . .	25 ,, ,, ,,	33	0·7
Camomile . .	6 ,, ,, ,,	11	0·55
Turpentine (in shade . .	10 ,, air . .	14	0·75

The experiments recorded in the next table were conducted by charging a number of very long sealed tubes with equal volumes of air, oil, and water, and exposing them to summer sunlight for a few hours, and not sufficiently long for the whole of the atmospheric oxygen to be absorbed in any single instance. The residual, unabsorbed gas was afterwards measured in the laboratory. Calling the largest amount of oxygen absorbed 100, then—

1. Russian oil of turpentine absorbed 100
2. Swedish ,, ,, ... 100
3. Some turpentine which was obtained in Geneva absorbed 89·4
4. American oil of turpentine absorbed . . . . . 78·9
5. Oil of eucalyptus absorbed . . . . . 75·0
6. An evidently adulterated Swedish turpentine absorbed . 52·6
7. " Scotch-distilled American turpentine " absorbed . . 42·1

* Ether also absorbs oxygen, and forms peroxide of hydrogen. See Parts I. and IV. of the research.—AUTHOR.

The oils numbered 1, 2, 4, and 5 were undoubtedly genuine commercial oils; the oil 3 was, perhaps, French oil of turpentine, and in this case only was the sample rectified by distillation before making the experiment, since it had undergone great oxidation by keeping for many years. The oils 6 and 7 had been sent as samples, and were evidently not genuine; probably both had been largely adulterated with so-called pine-oil of commerce.

The absorption of oxygen (even from the atmosphere) by essential oils and their true chemical terpenes, takes place at the ordinary temperature, although, of course, it happens more slowly at a low than at an elevated one; more slowly, therefore, in winter than in summer; more slowly in shade than in direct sunlight; more slowly in the dark than in diffused daylight; and in all cases, even if pure oxygen be used instead of air, the products are identical.

Now, if the pure hydrocarbons obtained from essential oils be placed in contact with a mixed solution of iodide of potassium and starch, they will not colour this test * mixture at once, but only after standing some time exposed to the air. On the other hand, if the experiment be made with those hydrocarbons which have been previously allowed to absorb oxygen from the air, a colouration is produced at once. The potassic iodide is decomposed; iodine

* This mixture has been stated in a previous chapter to be a test for both peroxide of hydrogen and ozone.

is set free, and this combining with starch, forms a blue compound, causing the colouration in question. Similarly, if the essential oils be exposed to the air in shallow vessels covered loosely with bibulous paper soaked in the same test mixture, the colouration is seen to take place, in time, upon the paper. That is to say, the oils evaporate slowly, and combining with atmospheric oxygen, produce the active principle, whatever it may be, which thus comes into contact with the test-paper and influences it. If the evaporation be assisted by placing the vessels upon a warm metallic plate, the reaction is obtained more speedily and is of a more intense character.

If, instead of soaking the paper in the above named mixture, it be moistened with acetate of lead, or sulphate of manganese, no colouration is then produced; nor are solutions of these respective substances coloured, even when placed in contact with the oils themselves, and on free exposure to the air. This fact seems, at once, to indicate that the active agent is not ozone; for if it were, affirmative results would be obtained.

Moreover, Soret proved that oil of turpentine readily absorbs ozone;* it is therefore utterly

* I have since confirmed this statement, and have ascertained that by the action of ozone upon turpentine, a substance is produced which yields peroxide of hydrogen on treatment with water. It is therefore probably identical with the peroxidised substance which results from the atmospheric oxidation of turpentine. (See my paper *Journ. Chem. Soc. Trans.*, 1880, p. 800.)

impossible that a substance which absorbs ozone should also produce it under identical conditions.

After studying the influence of peroxide of manganese, peroxide of lead, and hyposulphite of sodium upon oxidised oils containing the active principle, and having observed that these substances totally destroyed it, a fact of an important nature was experienced.

Some quantities of the oils of turpentine and caraway were, severally, oxidised to a considerable extent; then washed with water to remove any peroxide of hydrogen,* and finally introduced into vaccuous bottles containing mixed potassic iodide and starch, when the blue colouration was at once produced. It having been proved that the active principle, as directly formed, could not be ozone, and as the method of experiment excluded the possibility of its identity with peroxide of hydrogen, this new fact admitted of one explanation only, which is as follows :—

The essential oils absorb oxygen from the air, and also pure oxygen and ozone, and there is thus produced an additive product of an organic nature, exhibiting properties like those of ozone and peroxide of hydrogen; in other words, an organic peroxide is produced.

By perfectly distinct methods, Sir B. C. Brodie and others had previously fully established the

* It was previously ascertained that any peroxide of hydrogen either contained in, or attached to, the oxidised oils is entirely removed by washing them with water.

existence of such peroxides, and no doubt was felt but that the experiments above described also established the same fact in quite a new manner.

At the same time, it was observed that the active principle of oxidised oil of turpentine is entirely destroyed by heating it in contact with dry chloride of zinc to a temperature of 75°C.; whereas, in absence of the chloride of zinc, it was not affected by being heated to this point. Similarly, other dehydrating and deoxidising substances were found to destroy the active agent.

Having got so far, steps were next taken to more particularly ascertain the precise conditions upon which the formation of the active substance depends, and it was found to be produced whenever oil of turpentine (for example) is placed in contact with air only; that is to say, it was ascertained that the presence of water was not essential. It was noticed, however, at an early stage of the research, that the production of the active substance was much facilitated by carrying on the oxidation of the oil (by means of a current of air) in the presence of water, at a slightly elevated temperature; and in order to obtain further information, great quantities of turpentine were oxidised in this way. It at first appeared strange to find that the water standing underneath the turpentine after these experiments, contained, beyond question, peroxide of hydrogen. With the potassic iodide and starch mixture it gave the blue colouration; with chromic and sulphuric acids it also gave the characteristic reaction wherein

the violet perchromic acid is first produced, and subsequently decomposed with evolution of oxygen; while it evolved oxygen gas when treated with an acid solution of permanganate of potassium. In brief, there was obtained an aqueous solution containing so much peroxide of hydrogen, as to be capable, when decomposed, of evolving twice its own volume of oxygen gas.

It was thus proved that in the oxidation of oil of turpentine neither ozone nor peroxide of hydrogen is directly produced, but that the active substance which is first formed, yields peroxide of hydrogen as a secondary product when treated with water. So that if the oxidation takes place originally in the presence of water, peroxide of hydrogen is obtained in the aqueous solution.

All these observations accorded with the conclusion that the oxidised compound first produced is an organic peroxide; and as Brodie had described a method for the production of camphoric peroxide, it seemed that my product might be this same substance.* In any case, it may be supposed to

* More recently (*Journ. Chem. Soc. Trans.*, 1884, pp. 93—99) I have repeated the experiments made by the late Sir Benjamin Brodie, and have shown that camphoric peroxide, or rather a compound of it with barium, is not produced by acting with peroxide of barium upon camphoric anhydride. He represented the reaction by the equation :—

$$C_{10}H_{14}O_3 + BaO_2 = C_{10}H_{14}BaO_5 ;$$

whereas I have shown that the reactions which really take place are as follows :—

$$C_{10}H_{14}O_3 + H_2O = C_1\,H_{16}O_4$$
$$C_{10}H_{16}O_4 + BaO_2 = C_{10}H_{14}BaO_4 + H_2O_2.$$

be decomposed by contact with water as here represented:—

Camphoric peroxide + water = camphoric acid + peroxide of hydrogen.

$$C_{10}H_{14}O_4 + 2H_2O = C_{10}H_{16}O_4 + H_2O_2.$$

This idea received support from the fact that I found camphoric acid in the aqueous solution accompanying the peroxide of hydrogen, and some of its compounds were prepared and analysed. But whether my camphoric peroxide has or has not the composition here represented, it is, at any rate, slowly decomposed by contact with water, and the aqueous solution is found to contain peroxide of hydrogen, camphoric and acetic acids, also thymol and a soluble camphor.

The great proof that peroxide of hydrogen only results as a product of secondary decomposition, was afforded by the observation that when the oil is oxidised in the absence of water, and afterwards agitated with large volumes of water, it still retains its active properties, and yields more peroxide of hydrogen on further standing with water. The oxidised oil may even be dissolved in spirit and poured into water, and yet, after separation, it will retain some undecomposed camphoric peroxide. This may

That is to say, the camphoric anhydride is first resolved by contact with water into camphoric acid, and this, by reaction upon the peroxide of barium, yields camphorate of barium and peroxide of hydrogen.

This investigation, however, leaves the existence of my peroxide, obtained by the air-oxidation of terpenes, where it was, and in the absence of better knowledge I call it camphoric peroxide.—AUTHOR.

be well shown by mixing it with potassic iodide and starch (in the presence of a suitable acid), and estimating the iodine thus set free by means of a standard solution of thiosulphite of sodium. If the oxidised oil contained peroxide of hydrogen in mere admixture, this latter substance would be entirely removed by simply shaking with water: this, however, is not the case. When the strongly oxidised oil of turpentine is placed in a retort and heated to 160°C. (the boiling point of pure turpentine), the temperature suddenly rises spontaneously, effervescence sets in, and much gas, containing, I believe, oxygen, pours out with the vapour of the boiling oil.

Being anxious to establish some kind of relation between the terpenes of turpentine and the other essential oils, as also to obtain some further explanation of the facts which had been discovered, the later method of experiment—viz., oxidation in presence of water by a current of air—was extended to various different substances. Those examined at that time were:—

Cymene, $C_{10}H_{14}$ (from several different sources).
Hesperidene, $C_{10}H_{16}$ (the terpene of oil of orange-peel).
Myristicene, $C_{10}H_{16}$ (,, ,, ,, ,, nutmeg).
Menthene, $C_{10}H_{18}$ (from solid Japanese camphor).
Oil of wormwood (containing, according to Wright, much $C_{10}H_{16}O$, and a little terpene $C_{10}H_{16}$).
Oil of citronella (containing much $C_{10}H_{18}O$, and *no terpene*).
Yghlan Yhlang (containing no terpene).
Hydrocarbon from oil of cloves, being $C_{15}H_{24}$, as shown by Church.
Patchouli (containing no terpene).

The cymene from every source yielded peroxide of hydrogen in the aqueous solution, as did also all the terpenes as well as those oils which contained even the smallest quantity of terpene; menthene ($C_{10}H_{18}$) behaved similarly. On the other hand, the hydrocarbon from oil of cloves ($C_{15}H_{24}$), and those oils which contained no terpene, gave no trace of peroxide of hydrogen.

From these and other experiments which need not be referred to in this place, two inferences may be made:—

1. That all essential oils (of which ordinary turpentine is illustrative), which contain a hydrocarbon represented by the formula $C_{10}H_{16}$, and all pure terpenes, give peroxide of hydrogen when their oxidised products are treated with water.

2. That the production of peroxide of hydrogen in this way is related to cymene, for both Oppenheim and Wright have proved that cymene may be obtained from all the true terpenes ($C_{10}H_{16}$),* and it has been shown that cymene gives peroxide of hydrogen, while menthene gives both cymene and peroxide of hydrogen.

These conclusions were subsequently confirmed by the observation made by Wright, that the $C_{15}H_{24}$ hydrocarbon from oil of cloves, which does not yield peroxide of hydrogen, fails to yield cymene when subjected to the process by which all true terpenes ($C_{10}H_{16}$) yield it.

* Dr. Tilden has also shown that all terpenes yield the Nitroso derivative $C_{10}H_{15}$ (NO).

Another confirmation was afforded by the experiments of Mr. M. M. Pattison Muir, who found * that oil of sage absorbs oxygen and produces peroxide of hydrogen. He afterwards showed that the oil contained a quantity of a terpene ($C_{10}H_{16}$).

Whatever worth, then, the above-stated hypothesis may have, the fact is established beyond doubt, that all oils which contain cymene or terpene (such as oil of eucalyptus and ordinary turpentine) give rise to the production of peroxide of hydrogen, when subjected to the process described in the foregoing pages.

To revert once more to the atmospheric oxidation of oil of turpentine. There are various kinds of this oil known to commerce, differing according to the species of tree from which they are obtained, and probably (to some extent) upon the climatic and geological conditions of the localities in which the trees are grown. Moreover, all turpentines are not alike in their power of absorbing oxygen, some absorbing it much more freely than others.

It has been further observed, in certain cases, that an oil of turpentine which absorbs oxygen from the air at any given rate, will absorb it much less rapidly if freed from accompanying oxidised substances, by distillation. In other words, when once the process of oxidation has begun, it continues more and increasingly rapidly, so that the greater the amount of oxidised matter contained in the oil, the greater the oxidation under given conditions.

* *Year Book of Pharmacy*, 1876, p. 561; 1877, p. 498.

From these facts it may be inferred that in nature, the process of oxidation which occurs in the immediate neighbourhood of the trees takes place, in all probability, much more rapidly than in the laboratory; since, as produced in the trees, the oil is accompanied with the products of oxidation, to which reference is above made.

It is indeed remarkable that turpentine, in the act of being oxidised, is capable of imparting to fresh turpentine the same and equal facility to absorb oxygen. The comparatively slow rate at which the atmospheric oxidation of fresh turpentine proceeds, and the greater rate attained after the molecules have undergone that change which induces a rapid oxidation, is seen by the following figures, which relate to an experiment conducted some years ago upon about thirty gallons of turpentine in the presence of water:—

After 37 hours'	exposure	to a	current	of air	100 cc. of the aqueous solution contained 0·0651 grms. H_2O_2.
„ 41	„	„	„	„	0·2000 „
„ 54	„	„	„	„	0·3000 „
„ 58	„	„	„	„	0·4500 „

As the oxidation of the oil goes on, its density gradually increases by the absorption of oxygen. This fact is illustrated by the following figures:—

In one experiment the original density of the oil of turpentine used was 0·864.

After 24	hours'	oxidation	it	was . . . 0·880
„ 28	„	„	„	. . . 0·881
„ 32	„	„	„	. . . 0·888
„ 44	„	„	„	. . . 0·949

In another experiment—

After 16 hours' oxidation it was . . .	0·8886
„ 20 „ „ „ . . .	0·8996
„ 26 „ „ „ . . .	0·9060
„ 39 „ „ „ . . .	0·9136
„ 46 „ „ „ . . .	0·9366
„ 48 „ „ „ . . .	0·9476
„ 300 „ „ „ . . .	1·2350

It thickens as it increases in density, and acquires a powerful odour, reminding of camphor and peppermint at once.

With the increase in the density of the oxidised oil, its boiling point also rises, as was shown by the experiment now to be described. The turpentine used in the experiment boiled as in column (1):—

(1) Original Oil.	(2) After 24 hours' oxidation.	(3) After 27 hours' oxidation.
10 per cent. distilled over at 157°C.	162°C.	165°C.
20 „ „ „ 159	165·5	166
30 „ „ „ 160	168	170
40 „ „ „ 160	171	171
50 „ „ „ 160·5	174	174
60 „ „ „ 161	181	185
70 „ „ „ 162	193	206
80 „ „ „ 164	210	—
90 „ „ „ 166	—	—

The results here tabulated were arrived at by taking 100cc. of each product, and subjecting to careful distillation, care being taken to record the temperature after the collection of every 10cc. distillate.

It has been stated above that, accompanying the peroxide of hydrogen in the aqueous solution which is obtained by atmospherically oxidising turpentine in presence of water, there is a small quantity of acetic and camphoric acids. The solution also gives all the reactions characteristic of thymol, and there is another substance present as a main constituent. When such a solution is evaporated to dryness on the water bath, all the acetic acid is dissipated in the vapour and the peroxide of hydrogen is entirely decomposed; there remains in the dish a dark-coloured matter which, when hot, is soft and viscid, and smells like melted sugar. On cooling, it sets into a hard, adhesive mass, only about 95 per cent. of which is then soluble in cold water. This soluble part, when analysed, was found to contain 63·245 per cent. carbon, 10·132 per cent. hydrogen, and 26·623 per cent. oxygen, from which percentage the empirical formula $C_{10}H_{18}O_3$ may be constructed. The aqueous solution of this new substance is intensely bitter, and possesses most remarkable antiseptic properties, of which more anon. I write of this substance as soluble camphor.

There is yet one other product which is present in the aqueous solution resulting from the oxidation of turpentine over water. It is obtained in the free state, by merely subjecting the solution to distillation, when it passes over with the steam, and condenses into a light-coloured oil of a peculiar camphoraceous odour. It is this constituent that assists the solution of the soluble camphor.

In recapitulation of the foregoing details, it may be stated that, when turpentine is exposed to the action of air it absorbs oxygen, and gives rise to the production of a peculiar organic peroxide which remains dissolved in the body of the oil, and communicates thereto properties resembling those of ozone and peroxide of hydrogen. Inasmuch as the oil is volatile, these properties are communicated also to the surrounding atmosphere. If the oxidised oil be treated with water, or what amounts to the same thing, if the oxidation of the oil be conducted in the presence of water, then, on examination, the aqueous solution is found to contain peroxide of hydrogen, and it is accompanied by thymol, soluble camphor of the provisional formula $C_{10}H_{18}O_3$, camphoric acid, acetic acid, and a volatile oil.

The same products are obtained by the atmospheric oxidation of oil of eucalyptus and every other essential oil which contains either cymene ($C_{10}H_{14}$), or a terpene (that is, a hydrocarbon of the formula $C_{10}H_{16}$).

This chapter may be fitly concluded by observing that my process of atmospheric oxidation of essential oils is an exact imitation of the one which necessarily occurs in nature in connection with every plant that secretes these so-called oils, and which is, of course, attended with the same results. So far, therefore, as the properties of pine and eucalyptus forests may be connected with the special presence of peroxide of hydrogen, these are at once explained. In the next chapter, experiments will be described to show that

all the different products are powerful antiseptics or disinfectants, and thus we shall finally be enabled to apply the derived knowledge in explanation of some processes of Nature's Hygiene, which have been described in an earlier place.

Before proceeding, however, to these fresh studies, it will be convenient to so far anticipate the contents of the next chapter, as to assume that the products of the atmospheric oxidation of turpentine possess sanitary properties valuable enough in themselves to make it desirable that they should be commercially available.

Since, in this manufacture, it is desired to obtain the products of the atmospheric oxidation of turpentine for the sake of their sanitary properties, it becomes at once evident that the best result will be obtained by bringing the greatest quantity of air into intimate contact with a given quantity of turpentine under stated conditions. In practice this is effected as follows. A number of specially made Doulton-ware receivers are charged with water and turpentine in the proportions found to be best by experience, and the contents are maintained at a temperature of about 140°F. by placing the receivers in vats of water heated by steam. Under these conditions a current of air is pumped through each receiver during a prolonged period varying in practice from 70 to 300 hours. Under these circumstances the air current carries with it, when leaving the receivers, a large quantity of turpentine (or whatever other essential oil may be in use), in the state of

vapour, and this is condensed by passing it into and out of various compartments of cold water, or up and down coke-scrubbers. The turpentine collects on the various surfaces of the cold water, or in the cisterns at the bottom of the coke-scrubbers, and from time to time it is drawn off and restored to the oxidisers. The chemical reactions which occur in these vessels have been already described in the preceding pages, so that here it is only necessary to recapitulate the main particulars. The turpentine absorbs the oxygen from the air which is forced through it, and it is thereby oxidised, giving rise in the first place to the production of camphoric peroxide; then by secondary reactions the various other substances characteristic of the aqueous product are formed. These secondary products at once dissolve in the water, which is below the turpentine in the receivers. At first, these changes proceed slowly, but they proceed with increasing rapidity from the first moment, the oil of turpentine growing yellowish red and thick as the operation goes on. It will be seen from this statement that the strength of the aqueous solution which forms underneath the turpentine depends to some extent upon the time during which the process of air-oxidation is carried on. At the start we have only water and turpentine in contact; but as the turpentine becomes oxidised, it yields to the water a large part of the substances formed by its atmospheric oxidation, together with those other substances which are produced by the secondary reaction of the water upon the oxidised oil.

The successful conduct of this process is not without considerable difficulty. It must be remembered that one of the ultimate products of the process is peroxide of hydrogen. This begins to form from the first moment, and continues to be produced during the whole time; but it is so readily decomposed again that, unless a number of precautions and conditions are carefully observed and maintained, there is a liability of obtaining a product containing no peroxide of hydrogen. Thus, if the temperature in the vats be allowed to rise too high, or if an insufficient depth of turpentine be kept in the oxidisers, there is a danger of decomposing the whole of the peroxide of hydrogen existing at the time of the neglect. On the other hand, if the temperature be too low, it is produced very slowly.

In fact, the producer seeks to effect the greatest possible atmospheric oxidation of turpentine in the least given time, obtaining thereby the oxidised oil and aqueous solution containing as much dissolved camphoraceous principles as possible, together with the maximum quantity of peroxide of hydrogen. This is done because, as will be explained hereafter, the oxidising powers of the aqueous solution are largely due to the presence of the peroxide of hydrogen, while the strictly antiseptic characters are mainly traceable to the camphoraceous ingredients, notable amongst these being the soluble camphor and thymol. This product, termed "Sanitas" fluid, is largely used as a household disinfectant and as an antiseptic wash. It is

colourless, non-poisonous, and does not stain linen.

At the termination of the manufacturing operation here so briefly traced, there remains in the receivers, floating upon the surface of the solution, a quantity of oxidised oil of turpentine containing a large amount of the camphoric peroxide (resembling in all its properties peroxide of hydrogen), also a large quantity of different oxidised substances at least identical in part with those existing in a dissolved state in the aqueous fluid. The oxidised oil ("Sanitas" oil) is much more powerful as an antiseptic and disinfectant than the aqueous solution, and it is now largely used as an antiseptic dressing and for the preparation of gauze, disinfecting emulsion, powder, and soaps, and other articles, also for fumigating sick rooms, and for the specific treatment of lung and throat complaints: it is also used for varnish making, and for bleaching wax and feathers.

CHAPTER XII.

PROPERTIES OF THE OXIDATION PRODUCTS OF THE ESSENTIAL OILS CONSIDERED AS ANTISEPTICS, DISINFECTANTS, AND OXIDANTS; WITH FURTHER NOTES ON PRACTICAL DISINFECTION.

THE present state of precise knowledge relative to infectious diseases is too imperfect in character to guide practical disinfection, if considered apart from the much more extensive and general knowledge forming the sum of human experience. In the first place, we have no absolute knowledge respecting the causes of many of the chief contagious diseases, while as regards the few with which micro-organisms have been established to have a near connection, the precise nature of the relation has not been determined in a single case. As a rule we may take it that when micro-organisms originate disease, they do so indirectly by the agency of certain chemical products representing the products of their life action in suitable media.

We are dependent to a large extent upon general knowledge in forming an opinion respecting the properties which qualify a disinfectant for universal use; and in estimating, therefore, the extent to which the

"Sanitas" products exhibit these properties we must make use of this more general knowledge, as well as the more precise information respecting the causes and mode of propagation of infectious diseases.

It is matter of certain knowledge that the process of putrefaction is an insanitary one; it originates disease, and it promotes the spread of disease. Innumerable outbreaks of disease have been traced to the putrefaction of animal and vegetable matters proceeding in or near human habitations. Now, we have seen that putrefaction, beyond doubt, is initiated by certain low forms of life. These micro-organisms or their germs are practically ubiquitous, and in themselves are harmless, so far as we know, since most of the air we breathe and the water we drink, abound with them. It is only when they introduce themselves into dead organic media that they develope and produce those poisons which are dreaded by sanitarians. Septicæmia, pyæmia, puerperal fever, putrefaction in wounds, etc., etc., and a number of foul diseases, all well known in the hospitals, are undoubtedly due to the action of these same poisons, and it may well be that certain other even more dangerous diseases have the same or a similar origin.* However that may be, almost the only means, at

* Since Sanitas exerts an influence over those living agents which cause putrefaction (be it of a destructive nature to, or one of interference with, the normal function of vibriones), it is perfectly reasonable to infer that it exercises a corresponding influence upon other mycrophytes, and that this is so, experiments fully bear out.—AUTHOR.

present available, for determining the practical value of a disinfecting material, consists in ascertaining its power to prevent putrefaction and to chemically alter the nature of the products of that process. It must be clearly understood that, whereas putrefaction is initiated by microbes, all processes of fermentation are caused by low forms of life, and there is no kind of evidence that such forms of life are in themselves harmful to man. The mould which grows in all damp, airy places, and the fungic growths which always attend upon slow decay, are examples of the micro-organisms now under consideration. So far, indeed, are such matters from being of a noxious character under ordinary circumstances, that, beyond doubt, they serve a most sanitary purpose. By their agency the whole grand process of eremacausis (slow decay or slow combustion) is carried out. It is this process which ultimately burns all animal and vegetable compounds into carbonic acid, water, etc., which purely chemical substances are then available by plant life which requires them for sustenance. We do not want, therefore, to prevent slow decay or to render inactive those micro-organisms which carry it out, but we only seek to prevent putrefaction and to arrest the activity of the agencies which cause it, when that process occurs in and near the dwellings of man.

Our first proposition, then, is as follows:—"In addition to certain other properties, a disinfecting material must be competent to prevent and arrest

putrefaction, considered apart from innocuous processes of fermentation."

Next, it is patent to all, that a chemical reagent intended for use as a disinfectant, need not be of the same strength or activity for all purposes. In other words, in certain cases a stronger form is required than in others. For instance, a reagent intended to preserve solid meat from decomposition, must be of a greater antiseptic strength than one intended only to preserve a dilute extract which might be made from a part of the same meat. Similarly, sewer-mud and the excreta call for the use of a stronger disinfecting material than, say, contaminated water or sweat. For whereas sewer-mud and excreta consist mainly of organic matters, and these largely solid; impure water and sweat contain but a relatively small proportion of organic solids liable to putrefactive change. Thus, sweat contains water as its chief ingredient, and only about 0·5 to 1·25 per cent. of solid constituents, and even these consist to a considerable extent of inorganic salts. It is, therefore, evident that the various matters which require antisepting and disinfecting, present every degree of potency presented between solid or exclusively organic matters, and dilute solutions or films containing scarcely any solid organic substances.

Our second proposition, then, is that, "A disinfecting material for public use is not required of the same strength for all purposes; indeed, two or more forms differing in strength are desirable."

Now, as matters of animal and vegetable origin

are universally distributed, and find their way not merely into dust heaps and the sewers, but float about in the air, abound in waters, and even attach themselves to articles of wear and furniture, it is quite impracticable to universally prevent the process of putrefaction. The process cannot be initiated or perpetuated if the matters (otherwise of a nature to undergo this process) are in intimate contact with oxygen; for Pasteur, who is the greatest authority upon this subject, has established the fact that putrefaction cannot set up, say, for instance, in an extract of beef, until all oxygen which may be present in the fluid has been first removed and consumed by certain other ferments of a vegetable nature. But, it is easy to understand that a variety of circumstances continually exist under which oxygen is shut out from direct contact with putrefactive vibriones, and immediately this happens, putrefaction sets in. Thus, although by proper methods of cleanliness and ventilation, a house may be set in order, especially if measures of disinfection are also resorted to, yet, as it is not possible to be always using disinfectants or ventilating or cleansing; or rather, since, generally speaking, these sanitary proceedings are not sufficiently borne in mind and practised, we meet from time to time with the process of putrefaction going on in our midst, and until very recent years this was specially the case in our hospitals. It is, therefore, necessary, not only that a disinfecting material should be able to prevent and arrest putrefaction, but it must also have the property of oxidising or otherwise

destroying the poisons to which that process gives rise. Hence, the third proposition is: "A disinfecting material should possess oxidising or such other properties, as will enable it to destroy the products of putrefaction and allied processes, as well as to prevent and arrest the processes which create them."

Lastly, it is evident that to admit of universal application, a disinfectant must not merely possess those qualities which we have already studied, but it must also have such other qualities as fit it for universal use. In destroying septic poisons, care must be taken that the remedy shall not of itself kill the people, and so also in disinfecting inhabited apartments, the disinfecting material must not be dangerous in use; neither must it stain linen, carpets, and furniture. All this is imperative; for if reliance be placed upon disinfectants which either poison or stain, that reliance will be misplaced, since such reagents cannot be used as they should be used, without destruction to life and property. Our last proposition, therefore, is, "A disinfectant qualified for universal use must not be poisonous in itself, and must give no stain. In other words, it must be fit for universal application, and hence must not be destructive to human life or property."

As is well known, most of the essential oils, and certainly those of turpentine and eucalyptus, exercise very decided antiseptic characters. But, since in nature, these oils, when generated into the atmosphere, undergo oxidation in the presence of moisture, we must test the properties of the products

of oxidation if we would obtain a proper understanding of the sanitary influences of the pine and the eucalyptus.

It was from the well-known oxidising effects of peroxide of hydrogen and its consequent use as a disinfectant, that I was first led to the investigation of this branch of the subject; and during the earlier experiments, it was ascertained that beyond its well-known and valuable powers of oxidation, it also exhibits very peculiar antiseptic properties. This was new to science.

The investigation was continued with the view of ascertaining and explaining the antiseptic and disinfecting properties of the aqueous solution (Sanitas fluid) and the oxidised oil (Sanitas oil), which are obtained by oxidising oil of turpentine, or oil of eucalyptus, by air in the presence of water.

The following experiments were communicated to the British Association Meeting of 1876:—

Experiments with Peroxide of Hydrogen.

The solution which was employed was one of what is called "10-volumes strength," that is to say, it was capable of evolving ten times its own volume of oxygen gas when decomposed in accordance with the following equation:—

$$H_2O_2 + H_2O = O.$$

One hundred cubic centimetres of the solution would thus furnish 1000cc., or a litre of oxygen gas.

The experiments were conducted during hot summer weather.

10cc. of the peroxide of hydrogen, added to 400cc. of fresh milk, preserved it from souring for six days. Oxygen gas was gradually evolved in the meantime. By the eleventh day only the mixture became thick and sour.

5cc. preserved 47cc. grape-must from fermentation for some twenty-four hours, after which bubbles of oxygen gas escaped; finally, the mixture had an apple-like odour.

5cc. preserved 15cc. of white of egg, mixed with 10cc. water, perfectly fresh for many days.

5cc. preserved 400cc. "bitter beer," unaltered for twenty-six days; it then soured; fungus did not appear.

5cc. preserved 30cc. flour paste for six days free from sourness and mould.

Now the real quantities of peroxide of hydrogen and decomposable substances employed in the above experiments stand about as follows :—

							Per cent. of H_2O_2=
0·304	grm.	H_2O_2 and above	400	grms.	milk	.	0·076 per cent.
0·152	,,	H_2O_2 ,,	47	,,	must	.	0·3 ,,
0·152	,,	H_2O_2 ,,	15	,,	white of egg solution		1·0 ,,
0·152	,,	H_2O_2 ,,	400	,,	beer	.	0·04 ,,
0·152	,,	H_2O_2 ,,	30	,,	paste	.	0·5 ,,

These experiments being only intended to show that peroxide of hydrogen possesses antiseptic and preserving powers, and not meant to determine the extent of such influences, at least demonstrated that its prophylactic energies are very great indeed.

Messrs. Guttmann and Frænkel, apparently unaware of this prior publication, gave confirmation to my results by some experiments which were published in Virchow's *Archiv*, and to which the *Lancet* (1878, vol. ii., p. 839) subsequently directed further attention. These experiments confirmed the fact that peroxide of hydrogen preserves urine and meat infusions from putrefaction, while it also prevents the fermentation of grape-sugar.

More recently still, the antiseptic properties of peroxide of hydrogen have been studied by M. Baldy, and also by MM. Paul Bert and Regnard.* After the publication of these researches I took occasion to bring my own earlier investigations to the knowledge of M. Paul Bert, and in reply he has acknowledged my claim of priority, and promised to admit and state it when presenting a forthcoming communication to the Academy of Sciences.

The peroxide of hydrogen employed by M Baldy was prepared after the well-known process of Thénard, care being taken to neutralise the solution by means of argentic sulphate, and diluting it before use so as to work with a solution capable of yielding about twice its own volume of oxygen when subjected to decomposition into water and oxygen. It is necessary to, here, interpose the remark that neutral solutions of the substance are by no means so stable as acid solutions; and the amount of acid required to attain this stability is very trifling. By the

* *Compt. Rend.*, 94. 1383—1386.

ordinary process of manufacture, however, a considerable amount of acid is liable to be left present; but this is not the case with my process of manufacture, and, the nature of the acid being entirely different, it presents no difficulty in the use of the product.

The observation made by M. Baldy late in 1881, viz., that a small quantity of the peroxide removed the fœtidity from twelve to fifteen litres of putrid water, and further trials, convinced him that peroxide of hydrogen is an antiseptic agent inferior in no respect to carbolic acid, and entirely free from the disagreeable and dangerous character of that compound.

MM. Bert and Regnard, confirming my earlier experiments, have shown that an extremely dilute solution of oxygenated water prevents the fermentation of glucose by the agency of yeast, prevents mycodermic growth in red wine, prevents the lactic fermentation in milk, and the putrefaction of albumin, etc. On the other hand, they found that this antiseptic agent was incapable of arresting the changes induced by soluble non-organized ferments, such as diastase, in suitable media. I, too, have for many years been aware of the fact that the peroxide exercises no effect upon the transformation of starch into sugar by means of saliva. The distinction thus arrived at is most important, because, if peroxide of hydrogen, or Sanitas fluid, be employed for internal administration, we have a guarantee that its presence in the system will not arrest nor interfere with the

many assimilative and other processes carried on in the living body by means of ferments of the pancreatic type.

Incidentally, it may be observed that the study of peroxide of hydrogen presents many interesting points of contact with M. Bert's investigations of the action of compressed oxygen. Demarquay is stated to have observed the singular stimulating effect which oxygen gas exercises upon wounds, thus inducing rapid cicatrisation; and Bert has thoroughly studied the influence of compressed oxygen upon organisms to which it is fatal, while it leaves soluble non-organised ferments intact.

It is also of importance to bear in mind the remarkable attenuating influence which M. Pasteur has found to be excited by oxygen upon such morbific germs as the micro-organisms of chicken cholera and splenic fever, to the existence of both of which peroxide of hydrogen will almost certainly, in my opinion, be found fatal.

It was to be expected, from what has gone before, that this compound would be found of peculiar benefit for the treatment of wounds, and, indeed, throughout the whole range of antiseptic surgery; and the expectation has been amply realised in the practice of M. Baldy, M. Regnard, and in particular of M. Péan, in the hospital of St. Louis. To be brief, it has been demonstrated beyond question that all wounds treated with peroxide of hydrogen have progressed well, healing by first intention, and giving no trouble whatever, all discharges having been healthy in

character and free from odour. Chronic ulcers, similarly treated, have yielded equally good results; so also have cases of gangrene been successfully dealt with, together with fœtid suppurations and bad ozœnic discharges.

M. Péan has performed many important operations in an atmosphere impregnated with oxygenated water, instead of carbolic acid, with more than an average amount of success; and M. Baldy has employed gauze and wool soaked in the peroxide, and kept in contact with wounds by means of bandages, in cases where prolonged contact has been desirable. He has also found that it may with safety be used as an injection for washing out cavities of the body; and he hopes to derive much benefit from its internal administration, particularly in the treatment of diabetes and certain pulmonary affections.

The oxidising effects of peroxide of hydrogen upon animal and vegetable matters in a state of incipient change, or even of advanced decomposition, have been already considered in an earlier chapter. Nevertheless, its disinfecting properties are so important that it may be well to quote the following passage from Dr. Fox's work on Ozone (p. 228):—

"Peroxide of hydrogen is one of those powerful chemical agents which are concerned, like ozone, in the maintenance of the purity of the air. No known substance surpasses hydroxyl, as Dr. Frankland calls it, as an oxidising agent. Professor Taylor says:—'The oxygen contained in it amounts to 94 per cent. by weight; and according to Pelouze, in its maximum

of concentration it will give off 475 times its volume of this gas. It has been employed as a disinfectant in sick rooms in the form of spray, with the greatest advantage; but is somewhat expensive for this purpose. It rapidly destroys all noxious gases, and is persistent in its action. The bodies of patients affected by the eruptive fevers are, by some physicians, bathed with it; whilst the clothes and letters of the sick are cleansed by sprinkling over them this oxygenated water.'"

Dr. Day, of Geelong, believed that it possesses the power of oxidising and annihilating the poisons of small-pox, scarlet fever, and typhoid fever, and has himself furnished some of the data * upon which he has arrived at this conclusion, which is evidently not without foundation. Between April 1873, and the same month of 1875, he treated fifty-one cases of scarlet fever, by anointing the bodies of his patients with lard containing peroxide of hydrogen; and in some cases he caused his patients to gargle a very dilute solution of the same reagent. Under this judicious treatment, there was extension of the disease to other persons only in four houses, and there were no deaths. Subsequently, Dr. Day treated other sixty-four cases, and of these only six proved fatal, whilst there was spreading of the disease only in three cases. These facts go far to teach the disinfecting value of peroxide of hydrogen; for while

* *British Medical Journal*, March 10th, 1877. See also a paper on "The Uses of Peroxide of Hydrogen." By C. E. Shelly, M.B., *Practitioner*, March, 1884.

theorists continue to talk at random about the germs of scarlet fever, there actually exists a substance which seems at once to cure the disease, and prevent the extension of the infection.

Although we cannot accurately define the precise manner in which the peroxide of hydrogen acts on the contagious matter thrown off from the skin, we know that diseased matter may be rendered powerless to infect; and among agents capable of exerting this kind of influence, peroxide of hydrogen must be placed in the highest position, and that owing to its powerful oxidising effects.

In another chapter, reference has been made to the further fact that septic vibriones are killed by peroxide of hydrogen even when that solution is extremely dilute.

So much for peroxide of hydrogen.

Experiments with Camphoric Acid ($C_{10}H_{16}O_4$).

Camphoric acid being also a product of the atmospheric oxidation of turpentine conducted in the presence of moisture, some experiments were made with it, and it was found weight for weight to exhibit even more powerful antiseptic characters than salicylic acid, to which, as also to carbolic acid, it is chemically allied in certain respects.

0·3 grm. camphoric acid was found sufficient to preserve 400cc. milk perfectly good for seven days in hot summer weather. After that time a scum formed, and only upon the eleventh day it was curdled and sour.

0·1 grm. of camphoric acid kept 50cc. of flour

paste good for eleven days. It went sour on the twelfth day.

0·1 grm. of camphoric acid preserved 50cc. grape juice permanently free from fermentation even when kept in a warm oven.

0·1 grm. kept 15cc. white of egg mixed with 10cc. water, fresh for twenty-one days. The mixture became mouldy afterwards.

0·1 grm. kept 200cc. "bitter beer" unaltered for eleven days in an open vessel. It subsequently became covered with mildew.

Experiments with the Soluble Camphor of the Empirical Composition ($C_{10}H_{18}O_3$).

Equally striking are the antiseptic effects of this product of the oxidation of turpentine which has been described in the last chapter. The experiments now to be described will sufficiently illustrate this fact.

A solution of white of egg * was made by beating up the whites of four eggs with a quantity of water and filtering from membranous parts. Upon examination, the solution was found to contain 3·97 per cent. albumin dry at 100°C. Next, a solution of the soluble camphor containing 1·664 per cent. was prepared.

One stoppered bottle was charged with 20cc. of the albumin and 30cc. water: the mixture grew turbid, and began to stink on the sixth day. The other bottle was charged with 20cc. of the albumin, 25cc. water, and 5cc. of the antiseptic fluid. This

* Experience has shown me that it is much better to employ a dilute extract of meat for experiments of this kind, the indications being much sharper.—Author.

mixture kept perfectly sweet for at least thirteen days. That is to say, 0·0832 grm. of the soluble camphor, deferred the putrefaction of the albuminous solution at least eight days.

This experiment was repeated with stronger antiseptic and albuminous solutions with confirmative results.

In another experiment 0·75 grm. of the camphor was dissolved in 110cc. of albumin solution (containing 0·8 grm. solid substance, dry at 100°C.). The mixture kept clear and good from February 10th, 1879, till April 21st, after which it was no longer observed. At that time, the solution contained its albumin in a perfectly unchanged state.

The Volatile Portions.

Antiseptic properties are also possessed by the more volatile portions of the solution (those to which the odour is chiefly due and which are obtained on distillation of the solution). This feature makes Sanitas more valuable, since it is thus competent to act as an air purifier apart from a similar action presented by the peroxide of hydrogen. It is therefore seen that every constituent of the solution in question, contributes towards its total effect as an antiseptic and disinfectant. Of course it will be understood that acquaintance had been made with the characters of the solution as a whole, so far as this was possible, long before the experiments on its individual constituents were conducted, and also long before the solution ever became known to the public in a commercial form, as Sanitas.

It is unnecessary to recite any experiments made with thymol (another constituent of Sanitas fluid), as its properties are so well known.

Experiments with "Sanitas" Fluid.

The following were the experiments which were first put upon record in regard to this fluid :—

Substance experimented with.	Amount of Sanitas used.	The Result.	Result in cases where the same amount of water, but no Sanitas, was employed.
40cc. water mixed with 10cc. white of egg.	5cc. after neutralisation with soda.	As fresh after 24 days as at first.	Began to stink on 2nd day.
50cc. Muscatel grape juice.	10cc. neutralised sanitas.	No observable fermentation.	Speedy fermentation of a normal character.
200cc. milk.	10cc. do.	Faintly acid 5th day; curdled on 7th.	Solid and sour on 3rd day.
60cc. urine.	10cc. do.	Unchanged so long as observed, viz., 7 days.	Bad 2nd day, and stank 3rd day.
10 grms. brain matter.	10cc. sanitas.	Sweet so long as noticed, viz., 15 days.	Bad on 3rd day.
100cc. milk.	10cc. do.	Sweet for 9 days.	Bad on 2nd day.
100cc. flour paste.	10cc. do.	Good for more than 19 days.	Stank on 3rd day.
160cc. milk.	10cc. do.	Kept for 7 days.	Bad on 2nd day.
160cc. beer.	10cc. do.	Good for more than 7 days.	Film on 2nd and bad on 3rd day.

The following experiments were made with a weaker antiseptic solution than that employed in the foregoing experiments.

A bottle was taken and charged with beer in apparently good condition, and containing 0·222 per cent. total acid, calculated as acetic. To this was added 0·14 per cent. of the Sanitas. The bottle was then closed with a cork, through which passed a bent tube sealed with water, and kept in a room subject to considerable fluctuations in temperature. Gas was slowly evolved, but it appeared on examination to be mainly oxygen evolved from peroxide of hydrogen present in the Sanitas, and not carbonic anhydride to any considerable extent. Upon examination after seven days, it was found that the total acidity of the beer had not increased, thus showing that, as demonstrated by previous experiments, Sanitas prevents the formation of acidity in beer by the action of secondary ferments.

This property of the fluid is now taken practical advantage of by brewers, many of whom employ it for this purpose instead of Salicylic Acid. It is said to be an excellent preservative of the Mash, and that the grains come out quite fresh and free from acidity. Similarly it may be used to preserve beer in the house.

A large piece of fresh, lean beef-steak was cut up into pieces of about one inch square; each piece was threaded with cotton, and then suspended in bottles containing ninety-six cubic centimetres of differently constituted solutions, composed of Sanitas and water, in the proportions given below.

Solution used.		Remarks.
Pure Sanitas, No. 2.		The meat kept perfectly good so long as observed (in this case 50 days, but in other instances so long as 600 days).*
Sanitas.	Water.	
7 parts	1 . .	Kept absolutely unchanged so long as kept.
6 „	2 . .	The same.
5 „	3 . .	Kept quite free from putrescence for 40 days.
2 „	6 . .	„ „ „ 13 „
Water only . . .		Began to stink on second day, and each day grew worse.

Even a 10 per cent. solution of No. 2 Sanitas retards to a considerable extent, the process of putrefaction, and if, then, the mixture be kept for many weeks, although the solution will smell badly, the meat itself will be seen to have suffered little or no change, and, so far as observed in many experiments, will dry up on exposure to the air, without further putrefaction. It seems that in the first stages of the immersion, the meat is so influenced by the sanitas that, while the extractive part which passes into solution may subsequently putrefy, it (the meat) is protected against such change: it presents a parboiled, healthy appearance, and is hard. In the

* Animal matters may be thus preserved indefinitely, and hence the solution is very useful for preserving anatomical and other specimens.

stronger sanitas solutions the meat presents the same parboiled look, and remains perfectly hard and sweet, while the solutions themselves also remain brilliant and good. This set of experiments just described was performed in vessels only loosely covered.

In another experiment, two pounds of fresh beef-steak were minced and extracted at 60° centigrade, with 720 cubic centimetres water. The extract was cooled, filtered from fatty matter, and equal quantities placed in stoppered bottles with the quantities of Sanitas, No. 2 fluid, shown below:—

Mixture.			When a putrid odour was observable.
Extract.	Water.	Sanitas.	
50 parts.	50	0 . .	Faint on the second day; very red and putrid on fourth day.
50 „	25	25 . .	Faint on thirtieth day; putrefaction advanced very slowly.
50 „	12·5	37·5 .	Good so long as kept—viz., forty-two days.
50 „	0	50 . .	The same, of course.

Many other experiments of this kind have been made, all confirmative of the same general results. The beef extracts are considerably bleached by the peroxide of hydrogen in the Sanitas, but generally speaking, the putridity, if and when it sets in, is coincident with more or less reappearance of the red colour, and the formation of a turbidity, which gradually grows into a deposit. Meat which has

been preserved in Sanitas solutions, dries up unchanged on exposure to the air.

The next experiment is given in illustration of the power which Sanitas exerts in retarding the fermentation* of flour paste. A quarter of an ounce of flour made into paste with ten cubic centimetres water, began to ferment distinctly on the third day; mould was beginning to form, and the distinctive odour attending fermentation of this kind was plainly perceptible. On the eighth day the mould appeared through the surface, and the fluid-layer at the top had become yellow, and of very bad odour. A similar paste made with ten cubic centimetres of Sanitas No. 2, instead of with water, remained absolutely unaltered for nine days. Then, a few white specks formed in the solution and grew slowly (not so rapidly as in the water paste). A paste made with twenty cubic centimetres of the same Sanitas remained quite intact for seventeen days, after which it was not observed. The vessels were only partially protected from the introduction of particles from without.

Pieces of fresh, lean beef, each two inches square, and half-inch thick, were immersed for two hours in the solutions given below, and then freely suspended

* In the immediate vicinity of the room in which these experiments were conducted, hay and straw were being continually handled. This would, of course, favour the institution of fermentation in the pastes. It is interesting to bear in mind that so far as one constituent of Sanitas is concerned, namely, peroxide of hydrogen, this might be considered to aid the development of fungi, seeing these respire, taking in oxygen and giving out carbonic anhydride.

in the air in a room kept at 60° Fahrenheit by day, but not heated by night (November).

Cubic cntmtrs.	Solution used.	Remarks.
100	Pure water . .	Solution became red and stank on third day, with turbidity.
100	10 % Sanitas, No. 2.	All these solutions remained free from red colour, turbidity, and smell so long as observed, viz., twelve days.
100	50 % „ .	
100	Pure Sanitas . .	

All the pieces of meat dried up, free from any trace of putrefactive change, so that the object of the experiment was partially defeated. However, the history of the solutions, affords some interesting information.

A large beef-steak was cut up into a number of pieces of one inch square every way. These were threaded, kept moistened, and allowed to pass into advanced putrefaction. They were then suspended in solutions of 100 cubic centimetres volume, and containing respectively, 12·5, 25, 37·5, 50, 62·5, 75, 87·5, and 100 per cent. Sanitas No. 2 fluid. To check the results one piece was suspended in water. This latter solution at once became red, and the putrefaction advanced daily; the meat gradually softened, became very red, and decreased in volume and weight as it decomposed. The solution containing 12·5 per cent. Sanitas blanched the meat, and removed the putrid odour. This, however, returned on the fifth day after, and the solution reddened again

slowly. In all the other cases the putrefaction was at once arrested and destroyed, and did not recommence during the twenty-seven days that the experiment was kept going. The pieces of meat presented, at the end of this time, the blanched, par-boiled appearance previously referred to. They were all perfectly sweet, and on exposure to the air dried up entirely free from decomposition. A similar experiment was made with pieces of mackerel with the same general results, but the fishy smell prevented attainment of equally precise results.

A strong fluid extract of beef was kept during four weeks in a warm room, until, in fact, it had become terribly putrid. Quantities of this were placed in stoppered bottles, and then to these solutions, Sanitas fluid No. 2 was added from a burette, until in each case, the putrefactive odour could be no longer observed after shaking. In this way it was ascertained that 30 cubic centimetres of the Sanitas fluid entirely deodorised 100 cubic centimetres of the putrid extract, thus confirming a property which has been referred to previously.

These latter experiments clearly establish the facts that Sanitas No. 2, even when diluted, say, with eight or ten times its bulk of water, is sufficiently powerful to prevent and arrest such putrefactive change as can ever be expected to occur upon the human body, or in inhabited apartments; and that when used in a less diluted or a pure state, its capacity for work increases accordingly. Sanitas, alone, of all fluid disinfectants, is perfectly non-

poisonous, stainless, and without corrosive properties. On the other hand, indeed, it is pleasantly aromatic in character, and is qualified for universal application. The use of Sanitas for diffusing into the atmosphere of inhabited apartments and sick rooms, presents a really great advantage; it easily parts with oxygen, and it thus atones somewhat for that which is used up in insanitary processes.

As regards the uses of the fluid in surgery, they may be said to be identical with those of peroxide of hydrogen, already enumerated when describing the properties of that substance. But in addition it possesses the valuable antiseptic properties of its other several constituents.

In four experiments made by Dr. J. W. Miller,* in which lymph was mixed with Sanitas fluid in equal proportions, and allowed to stand for eight hours and upwards, the disinfection of the lymph was complete; that is to say, its infectivity was quite destroyed.

Unfortunately, Dr. Miller did not make any experiments with Sanitas oil and emulsion, while the one experiment which he made upon Sanitas powder is worthless, because he only observed the effect of the small amount of vapour which it gives off at ordinary temperatures, and not that of the powder itself. Moreover, as a test of the power of Sanitas vapour, the experiment has no value.

Testimony to the value of Sanitas fluid as an antiseptic has also been given by Mr. A. Wynter Blyth.

* *Practitioner*, October 1884, page 264.

Experiments with Sanitas Oil.

It will be borne in mind that this substance is the other main product of my process of air-oxidising turpentine.

For the purpose of describing its properties, we will assume that the operation ceases when the density of the oil is 950 or thereabouts. In such case, it is no longer colourless like the original turpentine, but is of a deep golden brown colour, and exhibits a powerful and penetrating odour of camphor, being also suggestive of peppermint. If it be now subjected to dry distillation, a considerable yield is obtained between 120° C. and 140° C., but as the distillation proceeds, water also comes over, suggesting that the oil suffers some decomposition under these circumstances, as might be expected from chemical considerations. If continued for some time, the mass left in the retort sets, after cooling, into a more or less hard, black, pitch-like substance.

The amount of oxygen contained in the oil may be roughly estimated by determining the density of the oxidised oil, and multiplying the difference between this and that of the original turpentine, by the number of gallons produced. For instance, suppose we have 1,000 gallons of Sanitas oil with a density of 950, and say the turpentine at the start had a density of 865; the difference is 85, indicating, roughly, a gain of 0·85 lb. of oxygen to each gallon, and, therefore, of 850 lbs. to the 1,000 gallons. Now, as already stated, some of this oxygen, in all

probability, exists in the form of camphor and otherwise; but most of it is present in the form of the organic peroxide, which, by contact with water, forms peroxide of hydrogen. Indeed, instead of regarding the fixation of oxygen in the 1,000 gallons of oil as amounting to 850 lbs., we must really look to a figure sufficiently large to comprehend all the peroxide of hydrogen which has been likewise produced in any such operation, and this would, reasoning from certain actual manufacturing operations, raise the total oxygen fixed by about 150 lbs.

The sanitary value of Sanitas oil can be determined by at least three methods, intended respectively to ascertain (1) its power of oxidation, (2) its antiseptic properties, (3) its germicidal properties. I have confined myself to the first two methods, but, as a matter of fact, these cover the third to a large extent.

First, then, as to the power of oxidation. It has already been shown that turpentine, pure and simple, has no action upon acidified iodide of potassium; but so soon as it has absorbed oxygen from the air, or from pure oxygen, or has been subjected to the action of ozone, it is competent to decompose potassium iodide, setting free the iodine, by the estimation of which substance the oxidising power can be determined, just as in the case of peroxide of hydrogen or ozone itself, although less readily; less readily, because Sanitas oil is not miscible with, or largely soluble in, water. In consequence, when estimating the camphoric peroxide present in this

product, it is found that immediately the oil comes in contact with the acidified solution containing excess of potassic iodide, some iodine is liberated, and this may be at once estimated by titration with decinormal sodic thiosulphate; but the reaction is not yet complete, and from time to time, upon due agitation, so as to bring all parts of the Sanitas oil into intimate contact with the reagents, further quantities of iodine will be set free and must be determined accordingly, only stopping when no more iodine is liberated after a reasonable period of agitation.

The gradual formation of the peroxide in the Sanitas oil may be thus registered, and for the purpose of illustration I may give here the notes of one operation.

At the start, 100 cc. of the turpentine (sp. gr. 867) liberated iodine requiring 10 cc. of the standard thiosulphate.

				Thiosulphate.
When the density was	875	then 100 cc.	required more than	50 cc.
„	880	„	„	80 „
„ „	885	„	„	144 „
„ „	910	„	„	600 „
„ „	975	„	„	1000 „

This result signifies that, at the time when the operation was concluded, the oxidising power of the product was such that 100 cc. could decompose 16·6 grms. of potassic iodide, and consequently liberate 12.7 grms. of iodine. In other words, the oxidising power was such that, assuming the active oxygen could be obtained in the gaseous state, one gallon

of the Sanitas oil would give twenty-five litres, or between five and six gallons of that gas.

Now, it is hardly necessary to point out that a substance which will oxidise such a stable compound as iodide of potassium, will also oxidise any animal or vegetable substances, particularly if these same substances be in course of putrefactive decomposition, and thus complete the oxidation in a short time; whereas the preliminary action of bacteria and the completing action of infusoria would take an enormously greater time, and in the meanwhile afford a nidus for various *viri*, or be at least unwholesome. Not merely does Sanitas oil exhibit this powerful oxidising effect, but what is more, after this has been exercised to the full, it is capable of forming a new amount of active peroxide, which then becomes available for further work. This is because it contains a certain amount of that particular part of the original turpentine which most easily absorbs oxygen from the air, and because the manufacturing operation by which it has been produced has furnished it with a sort of enhanced power to assimilate oxygen in this way.

In treating of the antiseptic properties of Sanitas oil I shall be very brief, because the description of a few experiments will serve the purpose equally well as by detailing a much larger number.

A piece of beef, weighing 20 grms., was suspended in 100 cc. of water containing 0·5 cc. of Sanitas oil. It remained sweet for at least twenty-five days, the solution then being colourless. When 1 cc. of

Sanitas oil was employed, the experiment was continued for forty days, and the beef was then still sweet. In the absence of Sanitas oil a third piece of beef, placed under otherwise corresponding circumstances, became putrid on the third day, the solution becoming red and most offensive.

A quantity of fresh flour paste was made, and three portions of 100 cc. each were taken. To each of the first two 1 cc. of Sanitas oil was added; the third portion was left unprotected. The unprotected portion was stale and sour to smell after a few days, and after five days mildew appeared on the surface and quickly increased in amount until a thick yellow-green growth was obtained. In the other cases the Sanitas oil protected the paste from all apparent decomposition during from thirty days in the one case, to fifty days in the other case.

50 cc. of white of egg was diluted with 250 cc. of water, and portions of 100 cc. each taken. The unprotected portion was putrid within a week after the start, whereas the portions containing respectively 0·5 cc. and 1 cc. of Sanitas oil kept unchanged as long as observed, viz., fifty days.

In another experiment 200 cc. of urine, treated with one-half cc. of Sanitas oil, and agitated, remained good during the whole time observed, viz., 100 days.

Many other experiments have been made, but it is not necessary to detail them. They show that Sanitas oil is very much more powerful than the aqueous Sanitas in antiseptic energy; and, indeed, it ranks among the most energetic antiseptic solutions.

In passing, it may be useful to observe that this antiseptic influence is exhibited quite apart from its power of oxidation, and signifies, in all probability, a germicidal power; that is to say, the Sanitas oil either kills the germ-life which initiates putrefaction and disease, or else it effectually interferes with their normal functions.

As regards the uses of Sanitas oil, a few words will suffice. This preparation is by no means intended to supersede, in any degree, the use of the aqueous solution, but only to supplement it; indeed, while it is far too powerful in its action to serve the purposes for which the aqueous solution is intended, its physico-chemical properties do not qualify it to meet the same ends. It may be employed for adding to glycerine, or oils, or ointments, when these various substances are applied to the body, either during the peeling stages of several infectious diseases, or when any suppurative action or morbid process requires to be arrested. It can also be used for producing such a powerful spray for the antiseptic treatment of wounds as is often required. Further, its evaporation forms an excellent expedient for the fumigation of apartments inhabited by persons suffering from communicable diseases. An ordinary-sized room requires about one fluid ounce of the oil, which should be placed in a small metal dish, and evaporated by means of a Bunsen lamp or other appliance beneath, taking ordinary precautions to prevent the material catching fire; or, the oil may be evaporated upon the surface of water from a saucepan

or kettle. Any plane surface, such as is presented by flooring and walls, may be effectually disinfected by simply smearing or wiping it over with a cloth or brush dipped in the oil, and in such operations a very minute amount of the substance goes a long way, by reason of its superior spreading qualities. The oil is slowly volatile, and hence it is competent to act as an aërial disinfectant. Although not appreciably soluble in water, it may readily be made into an emulsion therewith by the agency of gum acacia, and indeed such a product is now made and sold for general disinfecting purposes under the name of Sanitas emulsion. This product can be used with advantage for watering streets in times of epidemics, and for the deodorisation of wooden pavements and offensive collections of any kind. It is also of value for washing animals and as a sheep-dip.

Sanitas oil is, of course, soluble in spirit, and readily mixes with any oil. Sprinkled over sawdust, it forms a most effective deodorant for use in urinals and other places where a fluid as ordinarily applied is too soon carried away from the scene of action. No doubt many other applications will occur to the minds of readers, but enough has now been said in illustration of the oxidising and antiseptic characters of this product.

One of the derived products of Sanitas oil is Sanitas powder, and in illustration of its properties a few experiments may be now described.

Experiments with Sanitas Powder.

A piece of lean beefsteak, about three inches square, was lightly rubbed over with two grammes of Sanitas powder. It was kept exposed to the air for thirteen days, and up to the end there was no putrefaction or other apparent change. It dried up sweet and good.

The experiment was repeated with the same quantity of powder, only in this case it was first mixed with five cubic centimetres of water, and applied to the meat as a wash. Consequently, not nearly the whole of the two grammes were finally placed upon the meat. It was kept for twenty days without any kind of change, except that it dried up.

A similar experiment was made also with the same quantity of 15 per cent. carbolic acid powder. The meat had a sour smell on the ninth day, and this odour persisted whilst the meat remained moist. Finally, it dried up.

Two ounces of flour were made into a paste, with two ounces of water. The paste was divided into halves; one half was well mixed with 1·63 grammes Sanitas powder, and the other with the same quantity of 15 per cent. carbolic acid powder. The mixtures were placed in test glasses, imperfectly covered with watch glasses. The Sanitas paste kept absolutely unchanged for fifteen days; then small tufts of a fungic growth appeared on the sides of the glass where the liquor had been drawn up by capillary

action out of contact with the Sanitas powder. It did not otherwise alter during the subsequent twenty-three days, but the mixture remained as good as at first. From the carbolic paste, a liquor separated, and this became gradually red. On the second day this was very distinct, and the colour gradually deepened to blood-red, a peculiar odour simultaneously developing, and the paste itself becoming discoloured to a considerable depth. These characters intensified during the thirty-eight days it was kept.

The whites of nineteen eggs were diluted with water until the whole measured 1,200 cubic centimetres. Quantities of eighty cubic centimetres each were measured out into so many stoppered bottles, and to each bottle a quantity of Sanitas or carbolic acid powder was now added, and the mixtures agitated from time to time. The quantities of powder used ranged from 0·1 gramme upwards. The albuminous solution containing 0·1 gramme Sanitas powder, kept quite unchanged for seven days, but became faint on the eighth day. All the other Sanitas mixtures kept perfectly unchanged for the whole period they were observed, namely, forty days. The mixture containing 0·1 gramme carbolic acid powder became faint on the second day, and decidedly stank on the third day. The mixture containing twice this quantity of powder became faint on the fifth day, and stank badly on the sixth day. The mixture with 0·5 gramme became doubtful on the twelfth day, but in this case the carbolic smell was

too powerful * to be certain about the observation, although in the smaller amounts there was not the slightest doubt about the putrefactive odour and the presence of active vibriones. A special examination of the carbolic solutions was made in every case, and it was found that each one gave a precipitate on boiling, showing that in no case had all the albumin been coagulated by the carbolic acid.

A large piece of beef-steak, weighing more than one pound, was left in contact with about half-a-pint of fluid extract of beef until the whole was very putrescent. Ten grammes of Sanitas powder were then added and the mixture agitated. In this way the putrescent odour was entirely destroyed, and only the smell of ammonia remained. The mixture was kept five days, and putrefaction did not recommence. This experiment was also made with rotten mackerel, with a like result.

A quantity of freshly voided urine was well mixed with some fresh fæces, and the mixture placed in a stoppered bottle of considerable capacity, with a sprinkling of Sanitas powder. The mixture was kept

* The sense of smell serves but little purpose in experiments with carbolic acid, except in cases where that reagent is present only in very small amount. Its own odour is so intense that it suffices, even in small quantity, to cover or hide the putrescent odour entirely. It must be remembered that carbolic acid is not known to exercise any chemical effect which might render it valuable as a deodoriser. It does not destroy bad smells like oxidising agents; it only covers them by means of its own vapour, which in itself is dangerous and hurtful.

for more than 200 days, and it was then free from putrescence and the life which causes it.

Before describing any further experiments, those already given prove that Sanitas powder is, weight for weight, more active in preventing putrefaction than 15 per cent. carbolic acid powder, and that it will do that which carbolic acid powder will not do, viz., destroy the poisonous products of putrefaction, when these have been previously allowed to form. It is also proved that Sanitas powder is competent, when present in very small quantity, to entirely prevent and arrest the process of putrefaction, even when circumstances, otherwise, are most favourable to that process.

In illustration of the deodorising powers of Sanitas powder one fact only needs mention. The Smithfield Club show, where there are hundreds of animals, including more than fifty pigs (not to speak of the huge attendance of visitors), has now been for some years annually deodorised by Sanitas powder and fluid, and this is done so effectually, that even the presence of the pigs cannot be detected by their characteristic odour.

In confirmation of my own investigation of the antiseptic and oxidising effects of the Sanitas products, I may extract the following notes from a report made by Professor T. E. Thorpe, F.R.S., of the Yorkshire College, Leeds:—

"(1) A piece of beefsteak suspended in water, containing one cubic centimetre of Sanitas oil, remained sweet for forty-five days, whilst a similar piece in water

containing no oil, was putrid on the second day; so also was a piece of steak to which $\frac{1}{10}$ of a cubic centimetre of Sanitas oil had been added—a solution containing $\frac{1}{2}$ cc. preserved the beef for four days. Flour paste and white of egg remain apparently unchanged for much longer periods of time under the influence of Sanitas oil. Flour paste containing $\frac{1}{2}$ cc. of the oil remained perfectly sweet so long as the observations were continued (forty-seven days). Solutions containing 10 cc. of white of egg, diluted with 50 cc. of water, experienced no apparent change in contact with $\frac{1}{2}$ cc. of the oil during the whole period of the experiments, whilst both the flour paste and white of egg solutions unmixed with the oil were sour and putrid within a week after being made.

"(B) Three cc. of Sanitas fluid, mixed with a solution of 10 cc. of white of egg and 50 cc. of water, sufficed to keep the solution sweet for twenty days; with 5 cc. of Sanitas the solution is still apparently unchanged. So, too, 5 cc. of the fluid prevented the souring of milk for twelve days. The same sample of milk, without the addition of Sanitas fluid, was sour on the second day. Sanitas fluid exerts a much weaker antiseptic action on beef extract, or beef suspended in water, than the oil. Thus, with .5 cc. of the fluid, both extract and beef were putrid in four days; without the addition of the fluid the samples were putrid on the second day. Flour and solutions of gelatine yielded similar results.

"(C) Mixed with two grammes of Sanitas powder, milk, white of egg, gelatine and flour, remained

unaltered during the whole period over which the observations extended. With smaller quantities of the powder, the substances were more or less decomposed at earlier stages. Thus with ½ gramme of the powder added to 10 cc. of white of egg, mixed with 50 cc. of water, the mixture was putrescent on the twenty-eighth day; in the case of the milk on the twelfth day; in that of the flour on the twentieth day. Beef extract and beef (solid) suspended in water remained sweet for seven days with 2 grammes of the powder.

"A piece of beef-steak rubbed over with 2 grammes of the dry powder, and a similar piece rubbed over with 2 grammes of the powder previously made into a thick cream by the addition of 5 per cent. of water, have remained perfectly sweet and sound up to the present time."

I am glad to know that since their introduction some few years ago, the use of the Sanitas disinfectants has become very general, not alone by the public and in private medical practice, but also by the Health Authorities and in the hospitals throughout Great Britain; and no better proof could be adduced of their positive value for preventing infectious diseases.

CHAPTER XIII.

PINE AND EUCALYPTUS FORESTS AND THEIR HYGIENIC INFLUENCES, TOGETHER WITH AN ACCOUNT OF THE TURPENTINE INDUSTRY.

I HAVE shown that for all practical purposes, most of the so-called essential oils, of which there are a great number, may be considered as identical in chemical composition. So that what has been demonstrated to be true regarding the changes induced by bringing air into contact with oil of turpentine and water, is also true of oil of eucalyptus.* This, however, is not merely a matter of inference, but one of fact, since I have examined the absorptive power of oil of eucalyptus for oxygen, and determined the fact that peroxide of hydrogen appears as an ultimate product of the reaction when it is conducted in the presence of moisture.

It has also been shown that the sanitary properties of pine and eucalyptus forests are undoubtedly due, chiefly at any rate, to the production in and around

* Messrs. Faust and Homeyer (*Deut. Chem. Ges. Ber.*, vii., pp. 63-66, and pp. 1429-1430) have shown oil of eucalyptus to consist mainly of terpene ($C_{10}H_{16}$) and cymene ($C_{10}H_{14}$). The oil of eucalyptus also contains an oxidised body, $C_{10}H_{14}O$, or $C_{10}H_{16}O$.

them of what may be called "natural Sanitas," or, in other words, the products of the atmospheric oxidation of their essential oils conducted in the presence of moisture.* The intensity of the process is materially enhanced by the aid of direct sunlight.

In addition to the facts already brought forward in support of this view, and of the further elucidation which follows hereafter, there is a fair amount of what may be called negative evidence. In the first place, other fast-growing trees do not possess, so far as is known, the power of freeing vast tracts of country from malarial fever; hence, this power cannot be due to the mere drainage of the soil. Then, again, both pine woods and eucalyptus

* The importance of essential oils as hygienic agents is well set forth by a report of Dr. Schomburgk (*Soc. of Arts Journal*, Aug. 22nd, 1879) on the progress and condition of the Botanic Garden and Government plantations at Adelaide, Australia. In this report it is stated that British India and Europe consume about 150,000 gallons of handkerchief perfume yearly, and the English revenue from eau-de-Cologne alone is about £8,000 a year, while the total annual revenue from imported perfumes is estimated at £40,000. One perfume distillery at Cannes uses no less than 100,000 lbs. of acacia flowers, 140,000 lbs. of rose petals, 32,000 lbs. of jasmine blossoms, 20,000 lbs. of tube-rose, besides other fragrant flowers.

Dr. Schomburgk points out that in Australia, mignonette, sweet verbena, jasmine, rose, lavender, *Acacia famesiana*, heliotrope, rosemary, peppermint, violets, wallflower, laurel, orange, and the sweet scented geranium, all grow exceedingly well—indeed, with greater perfection than elsewhere. Australia, then, promises fair to produce commercially, vast quantities of essential oils, which by their distribution and use produce hygienic results no less effectually than the eucalyptus, the chemical history of which is studied in this treatise.—AUTHOR.

groves are to be found in abundance upon hilly slopes and in mountainous districts, where, of course, there can be no waterlogging of the soil; and here the hygienic influence of these trees is felt just as much as in other places. The positive evidence is no doubt, however, the most important; and having already made ourselves acquainted with its nature, we may hereafter proceed to study its extent.

In a lecture* on the *Eucalyptus globulus*, Professor Bentley, who has made a special study of this tree, and the other members of the same genus, said: "In a lecture on the 'Eucalyptus,' which I delivered at the Royal Botanic Gardens, in Regent's Park, four years ago, I then stated my reasons for believing that the emanations from the leaves of groves of eucalyptus had some influence in destroying marshy miasms, and thus improving the healthiness of the district. Since then the very interesting researches of Kingzett have proved that under the influence of air and moisture, both peroxide of hydrogen and camphoric acid are formed from volatile oils—the former a powerful disinfectant, and the latter an antiseptic; and hence I think there can now be no doubt that the healthy influence of eucalyptus trees is, to some extent at least, and probably more than we imagine, due to the volatile emanations from the leaves under the influence of air and moisture, pos-

* *Pharm. Journ.*, May 4th, 1878. Prof. Bentley's former lecture was delivered on March 14th, 1874, and printed by order. Taylor & Francis, 1874.

sessing direct disinfectant and antiseptic properties, and thus destroying the injurious effects of paludal miasms."

In view of the proofs that have been adduced in previous chapters, we may go even further than this, and say that if not entirely, then at least mainly, the hygienic influences of the eucalyptus and the pine are to be attributed to the products of the air-oxidation of their essential oils.

The *Eucalyptus globulus* belongs to the order *myrtaceæ*, which furnishes clove, oil of cajeput, and the pimento. The oil smells like oil of cajeput, and has a mint like taste. It boils at 144°—177°C., and its Sp. Gr. is 0·917.

Eucalyptus amygdalina. The oil from this species is pale yellow, and has a camphoraceous lemon-like odour of a pungent nature. It boils at 165°C., and resinifies on exposure to the air. Sp. Gr. 0·881.

Eucalyptus oleosa. The oil has a camphoraceous odour, reminding at once of mint and turpentine. It boils at 161°—177°C. Sp. Gr. 0·911.

Eucalyptus sideroxylon. The oil boils at 161°—177°C. Sp. Gr. 0·923.

Eucalyptus goniocalyx. The oil boils at 152°—175°C., and has a very penetrating odour and pungent bitter taste.

Eucalyptus obliqua. Its oil boils at 171°—195°C. Sp. Gr. 0·899.

Eucalyptus odorata. The oil has a very aromatic odour. It boils at 157°—199°C. Sp. Gr. 899—922.

Eucalyptus rostrata. The oil is very much like

odorata oil in odour and taste. It boils at 131—181°C. Sp. Gr. 0·918.

Eucalyptus citriodora. The oil has a variable boiling point and a Sp. Gr. 0·868.

Eucalyptus corymboza. The oil boils at 174°—196°C., and its Sp. Gr. is 0·880.

Eucalyptus dumoso. The boiling point of this oil is also said to be variable. Its Sp. Gr. is 0·931.

Eucalyptus fissilis. Sp. Gr. of oil 0·936.

Eucalyptus longifolio. The oil boils at 195°—214°C., and its Sp. Gr. is 0·942.

Eucalyptus viminalis. The oil boils at 167°—178°C., and its Sp. Gr. is 0·925.

Eucalyptus mannifera, yields the peculiar sweet exudation known as Australian manna.*

Writing of the foliage of the Eucalyptus tree, Mr. H. N. Draper says † it is unlike anything seen in these islands. "It is pendulous, quivering, and evergreen; and the peculiar whitish appearance of one side of the leaves—due to a fatty or resinous secretion—is very characteristic. Till the tree is from three to five years old, the leaves grow horizontally, but afterwards they assume a pendent position. Instead of having one of their surfaces towards the sky and the other towards the earth, they are often placed with their edges in these directions, so that each side is equally exposed to the light." It has also been suggested that this

* See paper in *Zeitschr. des œsterr. Apoth. Ver.*, 1878, 402; and *Pharm. Zeitung*, 1879, 220.

† *Chambers' Journal*, March 26th, 1881.

arrangement of the leaves may have something to do with the large amount of water exhaled by the eucalyptus tree into the atmosphere. M. Vallée has shown that a square yard of the leaves of the *Eucalyptus globulus*, weighing about 2¾ lbs., gives off four pints (5 lbs.) in twelve hours. This rapid evaporation of water is greatly assisted by the very numerous *stomata* or breathing spores that exist on the under surface of the leaves. Each leaf possesses three hundred and fifty of these *stomata*. The flowers resemble those of the myrtle. As for the seeds of the tree, which are contained in the fruit they are very minute, and it is said that one hundred and sixty thousand plants can be raised from a single pound weight of them.

In Australia, the Eucalyptus commonly attains a height of from 160 to 200 feet, and there are records of trees even 350 feet in height.

The oil of eucalyptus, as obtained from the different species, of which there are more than 135, is practically of one and the same composition, although the odour, which is generally rich and camphoraceous, differs a little in the yields from the various kinds of tree. The oil is chiefly stored in those pellucid glands which spread throughout the leaves, and which may readily be seen by holding up the leaves to the light. It is, however, to be found more or less throughout the tree.

M. Cloez found* that ten kilos of fresh leaves,

* *Chem. News*, vol. xxvi., p. 63.

taken from the branches of an Eucalyptus (species not named) which was killed by frost at the end of 1867, furnished by distillation with water 275 grms., or 2·5 per cent. by weight of oil. In another experiment (species again not named) eight kilos of dry leaves, gathered at Hyeres, gave, after keeping them one month, 489 grms., or 6 per cent.* From completely dry leaves, which had been kept five years, he obtained only 1·5 per cent. of oil.

The percentages given in the following table,† representing the amount of oil contained in the foliage of different species of the Eucalyptus, were, for the most part, determined by Mr. Bosisto for the exhibition of 1862:—

Eucalyptus amygdalina (or narrow-leaved peppermint tree)	3·313
,, oleosa	1·250
,, leucoxylon	1·060
,, goniocalyx	0·914
,, globulus (or blue gum-tree)	0·719
,, obliqua (or stringy bark-tree)	0·500

The next table is compiled from the paper of M. Raveret-Wattel,‡ quoted in a previous chapter:—

Eucalyptus amygdalina	5·75
,, oleosa	1·25
,, sideroxylon	1·00
,, goniocalyx	1·00
,, fabrorum	0·50
,, woolsii	0·18
,, rostrata (or red gum-tree)	0·06

* Probably from *Eucalyptus amygdalina*, judging from the quantity.

† See *Chem. News*, vol. xxxix., p. 169.

‡ *Pharm. Journ.*, New Series, vol. iii., pp. 22 and 43.

It is thus seen that, although the *Eucalyptus globulus* is the best known species, being a favourite on account of the rapidity of its growth and the luxuriance of its foliage, it is by no means one of the richest oil-yielding trees; and as Baron Ferdinand von Mueller (Director of the Victorian Botanical Department, Melbourne) therefore thinks, this species is not so important from a sanitary point of view as some of the others. Indeed, Mr. R. D. Adams, who obtained his information from Baron von Mueller, writes: "The respective hygienic value of various eucalypts may, to some extent, be judged from the percentage of oil in their foliage," which also varies in quantity and quality as much as the oil.* Even in the same species the amount of oil varies somewhat, according to the locality and season.

Eucalyptus rostrata, one of the poorest in oils, grows well in periodically inundated places, and even in stagnant water which is not saline, and thus it is important for planting in malarious districts.

The Eucalyptus is indigenous to the temperate parts of Australia and Tasmania, where the temperature ranges from 52° to 72°F.

It is said that some species grow well in hot and others in cold climates, and thus there are eucalypts to suit the tropics of India and the more temperate regions in England. It must, however, be admitted that the English climate is, generally speaking, much too rigorous during the winter months for the

* *Chem. News*, vol. xxxix., p. 169.

young plants. Old trees would withstand these climatic influences, but the trees cannot grow old in England.

Mr. Draper had, at one time, twenty-five healthy saplings of the *globulus*, five years of age, of from ten to sixteen feet high, growing near Dublin, and one which was twenty-five feet high, with a stem twenty-two inches in circumference; but though he kept them during four ordinary winters, they were all killed by the very cold weather experienced in the winter 1878—1879.

At Tre Fontane, Mr. Draper, who has personally visited the place, says there are cultivated at least eleven varieties, some of which, such as the *E. viminalis* and *E. botryoïdes*, do best in humid ground, whereas *E. resinifera* and *E. meliodora* flourish best in a dry soil; the *gobulus*, however, will adapt itself well to all sorts of conditions.

In a lecture on "Forest Culture,"* Baron von Mueller stated that Mr. Bosisto, a citizen of Melbourne, was then largely exporting the oil of eucalyptus, and was producing about 700 lbs. a month. Since then, Mr. Bosisto, who has most industriously pursued this business, has given much further attention to the hygienic value of the Eucalyptus. He became convinced that its properties have some connection with the essential oil, and set himself to ascertain what he could about the quantity of oil and its probable sanitary effects, supposing it gets

* *Pharm. Journ.*, New Series, vol. ii., p. 628.

into the atmosphere through evaporation aided by warm winds. He writes: * "The evidence of oil evaporation might thus be stated—that the desert scrub gums, after a winter of average rainfall, supplied the air with a continuous and even quantity of aromatic vapour, and kept up a rigorous vitality throughout the summer, and that a short season of rain and a long dry summer diminished the formation of oil, and so lessened the exhalation; but, on the other hand, the species tending seaward increased their quantity after a short winter."

It is said that sometimes the aroma of the volatile oil can be detected in the atmosphere even when travelling in the bush.

Now, in a previous chapter, attention has been called to the report of Mr. Skene, setting forth the distribution of eucalyptus forestry over Australia, and using these figures, Mr. Bosisto calculated that the mallee scrub in the colony of Victoria would retain in the leaves at one time no less than 4,843,872,000 gallons of oil, and the seaward species 280,891,000 gallons. In another calculation applying to the whole of New South Wales and South Australia, he showed that 96,877,440,000 gallons of oil may be held at one and the same moment in the leaves of trees massed together, and occupying a belt of country over which the hot winds blow. In the face of these figures, few could hesitate to come to the conclusion that forced itself upon Mr. Bosisto,

* *Pharm. Journ.*, New Series, vol. v., p. 270.

viz., that the eucalyptus as a fever-destroying tree owes this power to the oil which finds its way into the atmosphere.

As already stated, and as proved again and again, the oil has of itself certain antiseptic powers. These, however, are intensified, and become disinfectant and oxidant in character, also, so soon as the oil is oxidised by the atmospheric oxygen in contact with moisture. This has been explained in preceding chapters. From what is there described, it is probable that every molecule of oil of turpentine or oil of eucalyptus gives rise in this process of oxidation to a molecule of peroxide of hydrogen, and one of the soluble camphor which has the approximate formula of $C_{10}H_{18}O_3$. Now if this be so, then 96,897,440,000 gallons of eucalyptus oil can and must produce in the atmosphere surrounding the forests no less than 92,785,023 tons of peroxide of hydrogen, and 507,587,945 tons of the camphor, not to mention thymol and the other products of oxidation.

This quantity of peroxide of hydrogen could oxidise a correspondingly large amount of organic matter, rendering it harmless; for instance, say vegetable matter which may be undergoing decomposition, and thereby producing malarial fever, until it becomes thoroughly antisepted, or oxidised, thereby removing the malarial poison. In this way the peroxide of hydrogen could part with nearly half its weight of nascent oxygen.

Then, again, the antiseptic powers of such an

immense quantity of camphor can be conceived, if we reflect that a solution containing only a few grammes to the litre is sufficiently strong to preserve animal matter, almost indefinitely, free from decomposition, as demonstrated by experiment.

I have not met with any figures showing the weight of foliage to the individual trees from which the sanitary value of a single tree could be estimated; but there can be no doubt that the sanitary value of even a single tree must be very considerable.

Now, what is true about the eucalyptus and its oil, is true also of the pine-tree and its turpentine, and on even a much more extensive scale. That this is so, is evident from the very great quantity of turpentine which finds its way into commerce; and even this amount, great as it is, represents but a mere fraction of that produced in nature.

Oil of turpentine is contained in the wood, bark, leaves, and other parts of the members of the *coniferæ*, and the method by which it is distilled from the exudations of pines and firs will be referred to hereafter.

According to Planchon,* the French oil of turpentine is produced particularly by the *Pinus maritima* and *Pinus pinaster;* the German oil is yielded by *Pinus sylvestris*, L., *Abies pectinata*, and *A excelsa*, D.C; the Venetian oil is extracted from *Larix Europæa;* and the English oil is a product

* See paper by Dr. Julius Morel, *Pharm. Journ.*, New Series, January 12th, 1878.

yielded from the American turpentines produced by *Pinus tæda*, L., and *P. Australis*, Mich.

Dr. R. Godeffroy * has also recorded a similar statement, and furthermore adds that the German oil is also obtained from *Pinus vulgaris*, *P. picea*, and *P. rotunda*. He says that pine cone oil (*oleum abietis pini*) is obtained by distilling with water the cones of *abies pectinata;* dwarf pine oil by similarly distilling the young tops and cones of *Pinus pumilio*, and pine leaf oil from the leaves of *Pinus sylvestris* or *P. abies*.

The Swedish oil of turpentine (according to Morel) is obtained by distilling the wood itself; it is characterised by its odour, and by the presence of certain empyruematic substances.

All these different oils are classified as oil of turpentine; they differ, to some extent, in their boiling points (average 160°C.), their specific gravity and their action on polarised light, but in a more ultimate chemical sense they are identical, and merely represent so many different isomeric forms of terpene ($C_{10}H_{16}$). As produced in nature, they are accompanied with certain oxidised products, and doubtless the natural resins and gums are formed by the action of atmospheric oxygen upon the terpenes existing in the trees.

The process by which the turpentine is generally obtained from the trees, consists in tapping them at regular intervals, and collecting the crude or brute

* *Pharm. Zeitung*, 1877, No. 81.

turpentine which constitutes a thick resinous mass, and is afterwards subjected to distillation, either with water, or steam, or otherwise.

It is certain that the hygienic influence of the Pine is much greater than that of the Eucalyptus, since it has a much wider and more extensive distribution in nature. Thus, Russia alone has 500,000,000 acres of forestry largely consisting of pine trees; while, as is well known, a large industry is carried on in turpentine products yielded by the pines and firs of not only Russia, but also France, Switzerland, Germany, Sweden, and Austria. The European trade, however, is not so large as the American one, which now furnishes most of the turpentine met with in commerce.

In illustration of the extent of pine forestry in America, it is interesting to notice a remarkable shower of pollen grains which fell in the north-eastern part of Pennsylvania on the morning of March 17th, 1879, and covered an area of more than 2,500 square miles. The pollen was that of *Pinus Australis* from the Southern States, and it was believed to have been carried a distance of over 500 miles.*

Curiously enough, a similar occurrence was recently recorded † as having been noticed at Windsor, Slough, and in that neighbourhood generally. The pollen, which was probably derived from *Pinus Syl-*

* *Hardwicke's Science Gossip*, June 2nd, 1879.

† See *Nature*, June, 1878.

vestris, and blown from Windsor Forest, was, at first, thought by the people residing in the district to be sulphur.

Even in our own country, pine woods abound, not merely in Scotland, but scattered over the entire area. They are to be found so near to London as Bournemouth, Upton, and Weybridge.

From this vast extent of pine forestry distributed all over the world, an incalculable quantity of oil of turpentine finds its way into the atmosphere, just in the same manner as does the volatile oil of the eucalyptus. Of course this process of oil evaporation proceeds far more rapidly in warmer climates, and is much more noticeable in our own woods in summer than in winter. All who have visited Arcachon, or our own woods at St. George's Hills (Weybridge), in the summer, must have remarked the delicious aromatic perfume of the atmosphere. On a warm day, the air is balmy with the odour of the oil which is being incessantly poured into it, and that of the products which result from its oxidation.

The benefit derived by persons suffering from throat and lung diseases, from residence in such places is enormously great and beyond cavil. By the natural atmospheric oxidation of the oils of eucalyptus and turpentine there is produced an almost illimitable amount of peroxide of hydrogen and camphoraceous matters which must, perforce, act according to their chemical natures upon the pestilence that may be floating in the air, and upon the animal and vegetable matters that may be rotting

in the soil, as also upon the poison which constitutes the virus of pulmonary disease.

What is done by pine and eucalyptus forests on this grand scale, is carried out in miniature by every plant or flower which owes its perfume to the essential oil which it secretes.

Governing bodies and the public alike should, therefore, never lose sight of the value of eucalyptus and pine plantations. Valleys and swamps may, by their agency, be freed from malarial fever; and in the place of a poisonous atmosphere, they substitute a state of balminess and purity, at once luxurious and healthgiving.

There is no necessity to dwell further on this theme, but I hope that enough has been said and sufficient evidence brought forward to conclusively prove that among the processes of Nature's Hygiene there are few more extensive, or more important, than that we have been considering.*

In conclusion, it will be of some interest to glance at the industries that are carried on in a turpentine farm and in connection therewith. It has been well said that the pine of the South Atlantic States is to the dwellers therein, what the palm is to the South American, and the bamboo to the Chinaman. They build their house with it, and construct their rude

* For further evidence concerning the relation of plants, generally, to hygiene, I may refer readers to an interesting article by J. M. Anders, *Pharm. Journ.*, October 18th and 25th, 1884. The author of that paper, however, has fallen into the mistake of calling ozone that which has been proved to be peroxide of hydrogen.

furniture, fences, carts, and farming implements with it. They also use it for heating and lighting purposes, and live upon the profits resulting from the extraction of the turpentine, resin, pitch, and tar from it.

The turpentine industry has gradually extended from the pine forests of North Carolina, southwards from Wilmington, through South Carolina and into Georgia, where it now centres, but it also extends to Florida, where state convicts are employed in "turpentining."

The extraction of turpentine does not unfit the trees for lumbering, so that large saw-mills are often found in close proximity to turpentine orchards.

The lands are almost worthless, and "boxing" of the pitch-pine trees for the gum constitutes the only industry of these districts.

There are several kinds of pine, including the white, spruce, yellow, Roumany, and pitch pine, which latter differs a little from the yellow, and is the only valuable one for "boxing."

It is said that the owners of these lands generally lease the "privilege" for the business, and receive about 125 dollars for each crop of 10,000 boxes. These boxes are cavities, of which there may be from one to four, cut into each tree near the ground, and hold about a quart each. Each crop of 10,000 boxes requires the service of one man only in the season, which lasts from March to September. If the bark of the tree above each box be hacked away a little every fortnight, then about three quarts of pitch or

gum is obtained from each box during the season. After successive seasons of hacking, all the bark that can be reached becomes removed, and the quality of the gum gradually depreciates in the sense that it yields less turpentine oil.

A still load of sixteen barrels of this crude gum, yields about eighty gallons of turpentine which fetches 40 cents per gallon, and ten barrels of residual resin which sells at 1·4 to 5 dollars per barrel, according to quality. The money produce of the turpentine is said to represent the profit of the industry.

Trees that are unfit for further boxing, (which happens in five or six years), and are not suitable for timber, are sometimes used in the manufacture of tar. In that case they are cut up and piled in a large hole in the ground, then covered with earth and burned in the manner that charcoal burning is conducted. The gum which is "sweated" out, flows off with the smoke through a channel provided for that purpose. Each "cord" of wood makes two barrels of tar which fetches 1·5 dollars per barrel, and costs 37½ cents to make. The charcoal is sold for fuel.

Experiments are being made at Georgia for sweating the sawdust from the mills in the same way as the "boxed out" trees, and it is said that each ton yields fourteen gallons of turpentine, three or four barrels of resin, and a quantity of tar.

The annual average yield of the State is put down at 175,000 barrels of resin and 35,000 barrels of tur-

pentine, and all this finds a market in the United States.

The distillation of the crude turpentine is carried on in copper stills, and is continued until the proportion of turpentine to water in the distillate sinks to one to nine parts.

The resin left in the still is drawn off and passed through a strainer, to separate it from twigs and other foreign substances.

Virgin dip—that is, the first exudation from a newly boxed tree—yields about five gallons turpentine to the barrel of 280 lbs., about 20 per cent. being left in the resin, in order to keep it of a good colour and value. "Yellow dip," or that obtained in after years, yields about four gallons to the barrel.

From North Carolina, the turpentine annually exported amounts to about 5,300,000 gallons, and the resin to 550,000 barrels.

Another account, which I believe refers to the industry as practised in France, is given in a paper by Dr. Julius Morel,* from which I have derived some of the following information:—

The tapping of turpentine may continue over one hundred and fifty years, and more profitably if, while the tree is young, it is allowed an occasional period of rest. The process of "hacking" is carried on during the months from May to September. A vigorous pine standing alone will yield annually twenty to forty kilogrammes (44 lbs. to 88 lbs.) of

* *Pharm. Journ.*, sec. 3, vol. viii.

"crude turpentine;" but if the trees be massed together, the individual yield amounts only to about five or six kilogrammes. As already stated, the product thus obtained is called crude, or brute turpentine. A sample which had been obtained from the Silver and Spanish fir-trees (Strasburg turpentine) was analysed by Caillot in 1830, with the following results:—

Volatile oil	33·50 per cent.
Resin insoluble in alcohol . . .	6·20 „
Abietine (kind of resin) . . .	10·85 „
Abietic acid (resin acid) . . .	46·39 „
Aqueous extract containing succinic acid	0·85 „
Loss	2·21 „
	100·00

During the flow of the crude turpentine, there forms upon the bark a concrete mass, consisting of crude turpentine from which the volatile oil has been evaporated by atmospheric influences. This concreted substance is known as "gum thus," or "galipot." A yet cruder product of the same nature is known as "barras."

The pure oil of turpentine is obtained from the crude turpentine containing it together with certain hydrated and oxidised substances (resins, etc.), by various processes of distillation. The distillation may be conducted in the presence of water, or in a current of steam, or in the dry state. The yield of oil amounts to from 15 to 30 per cent. of the crude product and averages about 25 per cent.

Strasburg turpentine is very siccative, and is furnished by the Pectinate fir-tree, Silver and Spanish fir-trees. This tree inhabits almost all the mountains of Central Europe, the Alps, Pyrenees, etc. It is common on the Vosges and in the Black Forest, where it constitutes high and dense forests.

Venice turpentine is not very siccative, and is yielded by *Larix Europæa*, or common larch. This tree will grow upon almost any soil, but prospers best in a clear, dry atmosphere, or a cold-bottomed soil. It thrives at 1,800 feet above the sea level, and attains a higher level even than the Scotch pine. A tree of fifty or sixty years of age can yield from three to five kilos of crude turpentine annually, for five or six years. Canada balsam, or Canadian turpentine, is siccative, and is obtained from *Abies balsamea*. Burgundy pitch is obtained from *Abies excelsa* DC., and contains a large quantity of resinous matter.

Chian turpentine acquired some reputation a few years ago as a cure for cancer, but conflicting testimony as to its value soon followed, and now again it is rarely met with.

Another branch of chemical industry is carried on with the resin which is produced as described. By further destructive distillation it is made to yield resin spirit, resin oils, and pitch, which latter substance is left behind in the retorts.

Oil of turpentine is chiefly used in commerce in the manufacture of varnishes, which may be described as solutions of gums or resins, made by

dissolving them in volatile solvents. When a varnish is spread over the surface of any object, the solvent evaporates and leaves behind a thin layer of the gums previously held in solution. The gums and other substances employed in varnish-making are very numerous, and include copal, shellac, dammar, sandarach, mastic, elemi, benzoin, animi, rosin, asphalt, etc. Among the most important varnishes are those made from copal gums. In order to dissolve these in turpentine, they have to be powdered and subjected to dry distillation at a temperature of about 360°C., until a loss of from 20 to 25 per cent. by weight is effected. The residual product can then be dissolved in oil of turpentine and linseed oil, and the product is copal varnish. While, however, the hard gums are quite insoluble in turpentine, I have found that Copal, Sierra Leone, and Kowrie gums readily dissolve in air-oxidised oil of turpentine (Sanitas oil) without previous distillation, and that product is now gradually coming into use for this purpose.

The use of Sanitas oil in varnish-making is important, because not only does it avoid the waste of 25 per cent. by weight of the expensive copal gums, but it increases the body of the resulting varnish by the oxidised substances which it contains, and it also avoids the objectionable darkening in colour which results from the distillation of copal. Sanitas oil, which is now manufactured by my process on a large scale, also dissolves shellac, mastic, dammar, and rosin very readily, and it is

said to be of commercial value for bleaching wax and feathers.

In conclusion, mention may be made of an industry now carried on at Humboldtsan (in Upper Silesia), Remda (Thüringen-Wald), Jonköping (in Sweden), Wageningen (in Holland), and elsewhere, in connection with the acicular leaves of pines, firs, and conifers in general. These are exhausted of their oil and then boiled with an alkali (strong solution of carbonate of soda), in order to remove the resinous substances they contain; after which, the leaves are converted into a kind of cotton or wool, termed pine or forest wool. This product is used as a wadding for upholstery purposes, and for stuffing mattresses, etc. It is also used to some extent as an absorbent dressing in surgery. It is said to have the pleasant smell of fir wood and to be repulsive to vermin, but its hygienic value as a pine product is insignificant, seeing that the substances which would give it a value are removed by the process of manufacture.

Mr. Thomas Greenish has shown, by a carefully conducted investigation,* that several articles now being sold in this country under the names of pine wool, fir tree wool, pine foliage forest wool or flannel, etc., etc., are nothing more or less than stained cotton or sheep's wool, or a combination of the two materials.

* *Pharm. Journ.*, November 15th, 1884.

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